CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS

PROPOSED REGULATION FOR THE VERIFICATION PROCEDURE FOR IN-USE STRATEGIES TO CONTROL EMISSIONS FROM DIESEL ENGINES

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In addition to maintaining long-standing efforts to reduce emissions of ozone precursors, the Air Resources Board (ARB or "Board") is now faced with a newer challenge, that of reducing emissions of diesel particulate matter (PM). In 1998, the ARB identified diesel PM as a toxic air contaminant. Because of the amount of diesel PM emitted into California's air, it is now by far the number one contributor to total ambient air toxics risk.

To address this large-scale health concern, the ARB adopted the Diesel Risk Reduction Plan in 2000. A significant component of the Diesel Risk Reduction Plan involves proposals to apply emission control strategies to existing diesel vehicles and equipment in on-road, off-road, and stationary applications. In order to effectively implement any of the emission control strategies for existing engines, ARB needs to ensure that emission reductions achieved by these strategies are both real and durable, hence the need for a verification procedure.

This report describes the proposed Diesel Emission Control Strategy Verification Procedure ("Procedure") developed by ARB staff to verify strategies that provide reductions in diesel PM emissions. Those strategies include but are not limited to diesel particulate filters, diesel oxidation catalysts, exhaust gas recirculation, selective catalytic reduction systems, fuel additives, and alternative diesel fuels. The primary function of the Procedure is to support the Diesel Risk Reduction Plan, but in light of California's persistent ozone problem, it will also evaluate technologies for reducing oxides of nitrogen (NOx) emissions.

Observance of the Procedure is voluntary. For verification, the Procedure requires applicants to fulfill various testing and information submittal requirements and to provide a specified warranty. The applicant must perform emission reduction testing, conduct a durability demonstration, demonstrate its product in-field, and submit results along with other information in an application to ARB following a prescribed format. To ease the financial burden associated with testing, staff proposes that any existing data the applicant may have be considered and evaluated to determine if it fulfills any of the Procedure's testing requirements. Prior to performing any testing, the applicant must submit a proposed verification testing protocol (at the discretion of ARB) and have it approved by ARB. If after reviewing the application ARB verifies the diesel emission control strategy, it will issue an Executive Order to the applicant stating the verified emission reduction and any conditions that must be met for the diesel emission control strategy to function properly. For an applicant to retain a given verification, staff proposes that the applicant pass in-use compliance testing, which is intended to ensure that production units in the field are achieving emission reductions which are consistent with their verification.

While primarily intended to support the Diesel Risk Reduction Program, the Procedure will also be used to support several other programs designed to reduce emissions from

in-use diesel engines. These programs include the Carl Moyer Memorial Air Quality Standards Attainment Program, the Lower-Emissions School Bus Program, and the Public Transit Bus Fleet Rule.

Although the U.S. Environmental Protection Agency (U.S. EPA) also has a diesel emission control strategy verification program, it is used to support a voluntary retrofit program where specific air quality objectives have not been adopted yet. In contrast, the staff's proposal is intended to support the Board's Diesel Risk Reduction Plan which lays out specific objectives and identifies proposed control measures. Thus, to achieve the Board's public health objectives, there is a greater need to ensure that diesel emission control systems are fully functional and durable. In spite of differences between the two procedures, staff from both agencies have worked together to harmonize key requirements where possible to minimize the applicants' economic burden.

Because no direct emissions benefits are associated with the staff proposal, no traditional cost effectiveness can be calculated. When staff proposes rules to implement in-use controls for the various categories of diesel engines, it will provide more detailed estimates, taking into account the specific issues associated with each category. This is a voluntary procedure. Accordingly, there will be no economic impacts associated with reasonable compliance with the regulation.

The proposed verification procedure, as described herein, would provide a way to thoroughly evaluate the emissions reduction capabilities and durability of a variety of diesel emission control strategies. The proposal provides sound guidelines for evaluation, while retaining the flexibility needed to reduce the burden on applicants and allow speedy implementation of the Diesel Risk Reduction Plan. The ARB staff recommends that the Board adopt new sections of 2700 to 2710, Title 13, California Code of Regulations, set forth in the proposed Regulation Order in Appendix A.

1 INTRODUCTION

State and local agencies have implemented many control measures during the last three decades to improve air quality. As a result, there has been a steady decline in both emissions and ambient pollutant concentrations. In particular, the number of Stage 1 Smog Alerts has dramatically declined over the last two decades. Nevertheless, ozone – the pollutant that has received the most attention from air quality regulators – still reaches unhealthful concentrations in several of California's air districts. The South Coast and San Joaquin Valley districts in particular must make significant progress if they are to achieve the national ozone standard.

Progress has also been made in reducing the ambient concentration of fine particles that is 10 microns and smaller (PM_{10}). However, exceedances of the State's PM_{10} standard continue to occur throughout the State. Further reductions are needed both in directly emitted particles, and in the emissions of precursors to secondary particles formed in the atmosphere.

In addition to maintaining efforts to reduce emissions that cause exceedances of both the ozone and PM_{10} ambient standards, the ARB is now faced with a newer challenge, that of reducing emissions of diesel PM. In 1998, the ARB identified diesel PM as a toxic air contaminant following a ten-year review process. A toxic air contaminant is an air pollutant which contributes to mortality or serious illness, or poses other potential hazards to human health. Most toxic air contaminants are volatile and are found primarily in the atmosphere as gases, but some are atmospheric particles or liquid droplets. Diesel PM is of particular concern, since it can be distributed over large regions, thus leading to widespread public exposure.

Because of the amount of diesel PM emitted into California's air, it is by far the number one toxic air contaminant. To address this large-scale health concern, the ARB adopted the Diesel Risk Reduction Plan in 2000. A significant component of the Diesel Risk Reduction Plan involves proposals to apply diesel emission control strategies to existing diesel vehicles and equipment in on-road, off-road, and stationary applications. Consequently, the first step in implementing any of the proposed diesel emission control regulations is verifying which control strategies will be effective in reducing emissions.

For years, the ARB has had a program to allow the sale of aftermarket engine parts. However, that program was created to ensure that a modification would not increase emissions, and is thus not appropriate to determine that a strategy reduces emissions and then to quantify that reduction. Thus, a new procedure was needed. This report describes that procedure, the Diesel Emission Control Strategy Verification Procedure (Procedure). The Procedure was developed by ARB staff to identify strategies that provide real and durable reductions in diesel PM emissions, as well as reductions in emissions of NOx which are ozone precursors. The primary function of the Procedure is to support the Diesel Risk Reduction Plan, but in light of California's persistent ozone problem, it will also evaluate technologies for reducing NOx emissions. The Procedure

encompasses on-road, off-road, and stationary applications and includes strategies such as alternative diesel fuels and fuel additives. The Procedure represents a cooperative inter-divisional effort that drew upon the expertise of staff in different areas as needed. Staff also worked with and will continue to work with the U.S. EPA on harmonizing the verification procedures between the two agencies.

While developing the Procedure, staff addressed several important issues such as durability, warranty, and in-use compliance testing. The durability and warranty tests ensure that verified strategies will perform as required during a specified time period. In-use compliance testing will allow ARB staff to confirm that production units are consistent with verified designs, therefore giving equivalent reductions. These considerations were incorporated into the proposed Procedure.

2 BACKGROUND

2.1 California's Air Quality Status

While California has made great strides in reducing air pollution in communities across the State, most Californians at times still breathe air that is harmful to health. Although some of the most obvious health impacts of pollution such as teary eyes and breathing discomforts caused by high levels of smog occur less frequently and affect fewer people, research indicates that many of us are still at risk from day-to-day exposures to air pollution. This research reinforces concern for pollutants that have long been targets for improvement – ozone, respirable particulate matter, carbon monoxide, and air toxics. The health impacts of air pollution – including lower lung growth, asthma attacks, cancer, and cardiac impacts such as heart attacks – still threaten the lives and well being of our children, the elderly and citizens who may be at special risk due to existing illness or high exposures.

Data from 1997 to 1999 indicates that five of the ten urban areas in the U.S. with the highest 1-hour ozone design values (all exceeding the 0.12 parts per million (ppm) 1-hour national standard) are located in California (ARB, 2001). Efforts to bring California's air districts into attainment have focused on reducing emissions of the ozone precursors, namely NOx and reactive organic gases. Diesel engines, in particular those in mobile applications, are significant sources of NOx, but emit less reactive organic gases. While most technologies for reducing NOx from diesel engines are not currently mature and tend to be costly, NOx reductions from this large source are essential if attainment is to be achieved.

Attainment of the standards for PM_{10} is a significant challenge. The PM_{10} problem is most prevalent in the western United States. Four of the six areas classified as serious PM_{10} nonattainment areas - the Coachella Valley, the Owens Valley, the San Joaquin Valley, and the South Coast Air Basin - are located in California. Because of the complex nature of the particulate matter problem, it will be many years before the standards are attained (ARB, 2001).

In addition to the criteria pollutants discussed above, ARB is also pursuing reductions in toxic air contaminants. To address this newly identified health threat, ARB developed and adopted the Diesel Risk Reduction Plan, described in the next section.

2.2 Diesel Risk Reduction Plan

Particulate matter emissions from diesel-fueled vehicles and engines are about 25,000 tons per year in California. These emissions come from a wide variety of sources including over one million on-road and off-road vehicles, about 16,000 stationary engines, and close to 50,000 portable engines. On-road engines account for about 27 percent of the emissions, off-road engines about 66 percent, with the remaining 7 percent from stationary and portable engines. With full implementation of the current vehicle standards on the books and vehicle turnover, diesel particulate matter will still be about 22,000 tons per year in 2010 and about 19,000 tons per year in 2020.

In 1998, following an exhaustive 10-year scientific assessment process, the ARB identified particulate matter from diesel-fueled engines as a toxic air contaminant. On a statewide basis, the average potential cancer risk associated with these emissions is estimated at over 500 potential cases per million. In the South Coast Air Basin, the potential risk associated with diesel PM emissions is estimated to be 1,000 per million people. In comparison to other air toxics the Board has identified and controlled, diesel PM emissions pose the dominant threat by being responsible for about 70 percent of the total ambient air toxics risk. In addition to these general risks, diesel PM can also present elevated localized or near-source exposures. Depending on the activity and nearness to receptors, these potential risks can range from small to 1,500 per million or more. As a result of this significant potential risk, when the Board identified diesel PM as a toxic air contaminant, it directed staff to convene an advisory committee of interested parties to engage in a dialogue on the steps that can be taken to reduce these emissions.

The Diesel Risk Reduction Plan is a very comprehensive plan to significantly reduce diesel PM emissions. The basic premise is simple: proposals to require all new diesel-fueled vehicles and engines to use state-of-the-art catalyzed diesel particulate filters (DPFs) and diesel fuel with very low sulfur content. Further, all existing vehicles and engines should be evaluated, and wherever technically feasible and cost-effective, required to install DPFs. Since the time of the drafting of the Diesel Risk Reduction Plan, staff has recently broadened the vision of the plan to incorporate not just DPF technologies, but any diesel emission control strategy for which significant emissions reductions can be verified.

In short, the Diesel Risk Reduction Plan contains the following three main proposed components:

1) New regulatory standards for all new on-road, off-road, and stationary diesel-fueled engines and vehicles to reduce diesel PM emissions by about 90 percent overall from current levels;

2) New emission control requirements for existing on-road, off-road, and stationary diesel-fueled engines and vehicles where determined to be technically feasible and cost-effective; and

3) New Phase 2 diesel fuel regulations to reduce the sulfur content levels of diesel fuel to no more than 15 parts per million by weight (ppmw) to provide the quality of diesel fuel needed by many advanced diesel PM emission controls.

The projected emission benefits associated with the full implementation of this plan, including proposed federal measures, are reductions in diesel PM emissions and associated cancer risks of 75 percent by 2010 and 85 percent by 2020. The measures contained in this plan will have a great impact on reducing the localized risks associated with activities that expose nearby individuals to diesel PM emissions. Other benefits associated with reducing diesel PM emissions include reduced ambient fine particulate matter levels, increased visibility, less material damage due to soiling of surfaces, and reduced incidences of non-cancerous health effects, such as bronchitis and asthma.

To ensure that the benefits just described are real, staff has developed a Diesel Emission Control Strategy Verification Procedure, which is the subject of this staff proposal. The Procedure is designed to ensure that emission reductions derived from the use of control strategies are both real and durable.

3 SUMMARY OF PROPOSED REGULATIONS

If an applicant chooses to follow it, the verification procedure for in-use strategies would require the applicant to perform emission reduction testing, conduct a durability demonstration, conduct a field demonstration, and submit results along with other information in an application to ARB following a prescribed format. If after reviewing the application ARB verifies the diesel emission control strategy, it will issue an Executive Order to the applicant stating the verified emission reduction and any conditions that must be met for the diesel emission control strategy to function properly. Verification also requires that the applicant provide a warranty to the end-user and conduct in-use compliance testing.

3.1 Application Process

Before formally submitting an application for the initial verification of a diesel emission control strategy, the applicant must, at the discretion of ARB, submit a proposed verification testing protocol for approval. In addition to describing the technology and outlining the applicant's plan for meeting the requirements of the Procedure, the applicant may also submit any existing data for ARB to determine if they may be used to partially satisfy any of the testing requirements. The proposal, like the application itself, must focus on verification of the strategy with a single emission control group.

The definition of an emission control group in brief is a set of diesel engines and applications defined by various engine and application parameters that are relevant to the performance of a particular diesel emission control strategy (see Section 4.2 for the full definition). Categorizing the diesel "universe" in this way instead of simply on an "engine family" basis, as is done for new engine certification, is an effective method for reducing the amount of testing needed. In the proposal, the applicant should suggest what the emission control group parameters and the parameters' values should be, based on the nature of its system. Ultimately, staff will work with the applicant to determine an appropriate set of parameters. After having developed preliminary emission control groups, the applicant must select one with which to verify its system.

Upon completion of all verification testing, the applicant may submit a formal application for verification. The formal application must include the results of the verification testing as described below. If after review of the application ARB chooses to verify the diesel emission control strategy, it will be classified as indicated in Table 1 below:

Table 1. Verification Classifications for Diesel Emission Control Strategies

Pollutant	Reduction	Classification
PM	< 25%	Not verified
	≥ 25% but < 50%	Level 1
	≥ 50% but < 85%	Level 2
	≥ 85%, or ≤ 0.01 g/bhp-hr	Level 3
NOx	< 15%	Not verified
	≥ 15%	Verified in 5% increments

Each verified strategy will receive an Executive Order in which ARB will specify the verification level and identify any terms and conditions that are necessary to support the verification.

After a diesel emission control strategy has been verified for a single emission control group, the applicant may apply for extensions of this verification to include other groups as well as design modifications. In both cases, the applicant may use additional test data, engineering analysis and justification, and any other information deemed necessary by staff.

3.2 Emission Testing Requirements

The applicant must test the diesel emission control strategy on an emission control group basis. Its selection of test engine and test fuel will factor into defining the emission control group for which the strategy is verified. The appropriate test cycles to use depend on the application, as shown in Table 2. The number of tests indicated in the table must be run both for baseline and control configurations. Additionally, backpressure and exhaust temperature must be recorded for each test run.

Table 2. Test Cycles for Emission Reduction Testing*

Test Type	On-Road	Off-Road (including portable engines)	Stationary
Engine	FTP Heavy-duty Transient Cycle (1 cold-start and 3 hot-starts)	Steady-state test cycle from ARB off-road regulations (3 hot-starts)	Steady-state test cycle from ARB off-road regulations (3 hot-starts)
Chassis	UDDS (1 cold-start and 3 hot-starts) and ARB approved test cycle described below.	Not Applicable	Not Applicable

*Additional hot-starts are required for NOx emission reduction between 15-25 percent. FTP = Federal Test Procedure; UDDS = Urban Dynamometer Driving Schedule

For NOx reductions greater than the minimum of 15 percent but less than 25 percent, test runs beyond those indicated in Table 3 are required. Each set of three hot-starts in Table 2 must be augmented to five hot-starts for 20-25 percent NOx reductions, and to nine hot-starts for 15-20 percent NOx reductions (see Table 3). The same applies for durability testing. Appendix D provides detailed statistics for determining the number of additional test runs.

Table 3. Hot-Start Test Requirements for Verifying NOx Reductions Between 15 and 25 Percent

NOx Reduction	Hot-Start Test Runs
$\geq$ 25%	3
$\geq$ 20% and < 25%	5
$\geq$ 15% and < 20%	9

For any diesel emission control strategy intended for use with on-road engines, verification of NOx emission reductions requires testing with an additional test cycle, proposed by the applicant and approved by ARB, which triggers any "defeat devices." Test repetitions are determined in accordance with Table 3.

In general, the applicant may request ARB to approve an alternative test cycle or method in place of a required test cycle or method. ARB will review the alternative using criteria described in the Procedure.

At a minimum, total PM, hydrocarbons, NOx, nitrogen dioxide (NO_2), carbon monoxide, and carbon dioxide emissions must be measured. In addition, ARB may require the applicant to perform additional exhaust analyses if there is reason to believe that the use of the diesel emission control strategy may result in the increase of toxic air contaminants, other harmful compounds, or a change in the nature of the emitted PM (such as the nano-particle formation). In its determination, staff may consider such factors as whether any substance is added to the fuel, intake air, or exhaust stream, whether a catalytic reaction is known or reasonably suspected to increase toxic air contaminants, results from scientific literature, field experience, and any additional data. All of this information will help staff to understand the potential adverse health effects associated with use of the diesel emission control strategy.

3.3 Durability Testing Requirements

The applicant must demonstrate, to the satisfaction of the ARB, the durability of the diesel emission control strategy's emission reductions. The durability demonstration consists of application of the strategy in the field or in a laboratory over some period of time or distance (indicated in Table 4) combined with emissions testing at the beginning and end of the demonstration period. If the applicant chooses a laboratory-based durability demonstration, an additional field demonstration test will be required to demonstrate in-field compatibility (see Section 3.4). Whether the applicant performs an in-field durability demonstration or the additional field demonstration, it must also provide a written statement from an ARB-approved third party, such as the owner or

operator of the vehicle or equipment used. The statement must describe overall performance, maintenance required, problems encountered, the results of a visual inspection, and any other relevant comments. The applicant may request ARB to accept an existing field demonstration.

Table 4. Minimum Durability Demonstration Periods

Engine Type	Minimum Durability Demonstration Period
On-Road	50,000 miles or 1000 hours
Off-Road (including portable engines) and Stationary	1000 hours
Stationary emergency generators	500 hours

For both the initial and final emission tests, the applicant must test the diesel emission control strategy using a test cycle(s) as indicated in Table 5. The applicant must use the same cycle for both sets of testing. If there are substantial test data from previous field studies or field demonstrations, applicants may request ARB to waive the initial emission tests.

Table 5. Emission Tests Required for Durability Demonstrations

Application	Test Type	Initial Test (0% of durability period) Final Test (100% of durability period)
On-Road	Engine	FTP Heavy-duty Transient Cycle (1 cold and 3 hot-starts)
	Chassis	UDDS (1 cold 3 hot-starts) and ARB-approved low-speed test cycle (3 hot-starts)
Off-Road and portable engines	Engine	Steady-state test cycle from ARB off-road regulations or an alternative cycle (3 hot-starts)
Stationary	Engine	Steady-state test cycle from ARB off-road regulations or an alternative cycle (3 hot-starts)

Note that baseline testing (without the diesel emission control strategy implemented) is required only for the initial test or the final test.

If, for off-road and stationary applications only, ARB is convinced that the diesel emission control strategy is technologically sound and appropriate for the intended emission control group, a conditional verification may be granted upon completion of 33 percent of the minimum durability period. Full verification is contingent on completion of the durability testing and submission of test results.

If the diesel emission control strategy fails to maintain its initial verified percent emission reduction or emission level during the durability demonstration period, ARB will downgrade the system to the verification level corresponding to the degraded performance. If the diesel emission control strategy fails to maintain at least a 25 percent PM reduction or 15 percent NOx (if applicable) reduction during the durability period, the diesel emission control strategy will not be verified. The applicant must submit a report explaining the circumstances of the failure. ARB will then determine if the applicant should continue the durability demonstration after fixing the failed system or begin a new durability demonstration.

3.4 Field Demonstration Requirements

The applicant must demonstrate successful operation and compatibility of its diesel emission control strategy in the field with at least one vehicle or engine belonging to the emission control group it chooses for verification. For most applications, the field demonstration test period is a minimum of 200 hours or 10,000 miles, whichever occurs first. For stationary emergency generators, the test period is 24 hours of simulated

maintenance because they are used infrequently. ARB will consider existing field experience and engineering justification to determine whether additional emission control groups require separate field demonstrations. If the durability demonstration selected is a field test (see Section 3.3), it may be used to satisfy the field demonstration requirement for that emission control group.

A written statement from an ARB-approved third party, such as the owner or operator of the vehicle or equipment used in the field demonstration, must be provided at the end of the test period describing overall performance, maintenance required, problems encountered, the results of a visual inspection, and any other relevant comments. If the strategy fails, the applicant must submit a report explaining the circumstances of the failure.

3.5 Other Requirements

- Engine Backpressure and Monitoring: During the emission and durability testing and field demonstration, the applicant must demonstrate that the backpressure caused by its diesel emission control system is within the engine manufacturer's specified limits, or will not result in any damage to the engine. Also, a backpressure monitor must be installed with all filter-based systems.

- Noise Level Control: Any diesel emission control system that replaces a muffler must continue to provide at a minimum the same level of exhaust noise attenuation as the muffler with which the vehicle was originally equipped by its manufacturer.

- System Label: The applicant must provide a label for each diesel emission control system which includes the diesel emission control strategy family name (see section 4.3.6.4) and other information.

- Other Informational Requirements: The applicant must describe fuel and oil requirements, maintenance requirements, provide an owner's manual, and additional information that ARB may require to assess environmental impacts associated with use of the diesel emission control strategy.

3.6 Limit on Nitrogen Dioxide

Measurements of NO_X emissions from heavy-duty diesel vehicles equipped with passive catalyzed filters have shown an increase in the ratio of NO_2 to nitric oxide (NO), while the total NO_X emissions remain approximately the same. Atmospheric modeling studies have found that an NO_2 to NO_X emission ratio of about 20 percent would nearly eliminate any impact of increased NO_2 emissions. The health benefits derived from the use of PM filters are immediate and offset the possible adverse effects of increases in NO_2 emissions. For this reason, staff proposes that a cap of 20 percent NO_2 to baseline NO_X emission ratio be established for all diesel emission control strategies (see section 4.3.4 for a more detailed discussion).

3.7 Warranty

The applicant must provide a defects and performance warranty with a minimum coverage as shown in Table 6. For each engine type and size, the warranty period is that which occurs first. The applicant must also include a copy of the prescribed warranty statement in the owner's manual.

Table 6. Minimum Warranty Periods

Engine Type	Engine Size	Minimum Warranty Period
On-Road	Light heavy-duty, generally 70 to 170 hp, Gross Vehicle Weight Rating (GVWR) normally less than 19,500 lbs.	5 years or 60,000 miles
	Medium heavy-duty, generally 170 to 250 hp, GVWR normally from 19,500 lbs. to 33,000 lbs.	5 years or 100,000 miles
	Heavy heavy-duty, generally exceeds 250 hp, GVWR normally exceeds 33,000 lbs.	5 years or 150,000 miles
Off-Road (includes portable engines) and Stationary	Under 25 hp, and for constant speed engines rated under 50 hp with rated speeds greater than or equal to 3,000 rpm	3 years or 1,600 hours
	At or above 25 hp and under 50 hp	4 years or 2,600 hours
	At or above 50 hp	5 years or 4,200 hours

3.8 Determination of Emission Reduction

The verification of a diesel emission control strategy's emission reduction by ARB will be based on the average of all valid emission and durability test results before and after the installation of the diesel emission control system. For applicants that are verifying that a diesel emission control system can achieve an absolute PM emission level of 0.01 grams per brake horsepower-hour (g/bhp-hr), a simple average of the test results will be used.

3.9 In-Use Compliance Requirements

The in-use compliance requirements apply to all diesel emission control strategies. In-use compliance testing is required when at least 50 units of a specific diesel emission

control strategy family have been sold in the California market, and consists of two phases.

In the first phase of in-use compliance testing, applicants must obtain and test systems which have been operated for at least one year or are within three months of their first maintenance, whichever comes first. Applicants must use the same testing procedure and test cycle(s) that were used in the strategy's original verification. A minimum of four diesel emission control systems must be tested. For each system tested that performs lower than 90 percent of the lower bound of its verified level, two more diesel emission control systems must be obtained and tested. This process is to continue as necessary, with the constraint that the total number of systems tested may not exceed ten. A system is in compliance if at least four units pass and at least 70 percent of all tested units pass. A unit passes if its emission reduction is greater than 90 percent of the lower bound of the initially verified emission reduction level.

In the second phase of the in-use compliance testing, applicants must obtain and test systems which have been operated between 60 and 80 percent of their minimum warranty period. The testing requirements are identical to those in first phase of in-use compliance testing.

If a system fails during either phase one or phase two of in-use compliance testing, the applicant must submit an investigative report detailing the causes of the failure. After completing all testing in a phase, the applicant must submit an in-use compliance report to ARB that includes information described in the Procedure. If a system does not pass, the applicant must submit a remedial report for ARB review. Depending on its evaluation of the remedial report, ARB may lower a strategy's verified emission reduction level or may revoke verification.

The staff's proposal includes a provision that if the structure or uniqueness of the industry in which the diesel emission control systems are used creates difficulty in conducting the testing described above, applicants may propose an alternative method for determining in-use compliance.

3.10 Special Requirements for Fuel-based Strategies

Some diesel emission control strategies rely on fuel changes either through use of additives or through use of alternative diesel fuels. Those strategies are subject to some specific requirements described below. Fuel based strategies must undergo review by the California Environmental Protection Agency Environmental Policy Council and comply with section 43830.8 of the Health and Safety Code requiring testing of multimedia effects. For a full description of these requirements, see section 4.3.5.

3.10.1 Fuel Additives

Additional requirements apply to diesel emission control strategies that use fuel additives. Fuel additives must be used in combination with a diesel particulate filter unless they can be proven to be safe for use alone. The applicant must submit the exact chemical formulation of the fuel additive. Every two years, the applicant must update the environmental, toxicological, epidemiological, and other health-related data pertaining to the fuel additive. Additive strategies which involve on-board storage of the additive must include fill-level monitors to notify the operator when refill is necessary. Finally, emission testing for additives with metal constituents must be replicated at high metal concentrations. See section 4.3.5.1 for more detail.

3.10.2 Alternative Diesel Fuels

The verification procedure also applies to diesel emission control strategies that involve use of alternative diesel fuels. Examples of alternative diesel fuels include but are not limited to biodiesel fuels, Fischer Tropsch fuels, and water emulsified fuels. The verification procedure for alternative diesel fuels follows that for other diesel emission control strategies, but has additional requirements including comparative testing and a description of fuel properties.

In each emission test of an alternative diesel fuel, exhaust emissions of HC, CO, NOx, and PM must be measured. The tests must be performed using an engine or vehicle from the emission control group chosen by the applicant for verification. If both hot and cold-start tests are performed then at least five cold-start and five hot-start tests must be conducted with both the alternative diesel fuel and the reference fuel using an engine or chassis dynamometer. If only hot starts are performed, then one of the test sequences described in the Procedure must be followed which consists of at least twenty or twenty-one tests with each fuel. The test cycles used to verify the fuel are the same as the test cycles used in the proposed test procedure (see Table 2).

In addition to the exhaust emission tests described above, the applicant must also meet the durability testing requirements described in Section 3.3. Following completion of the service accumulation, the applicant must provide data showing that the candidate alternative diesel fuel does not adversely affect the performance and operation of diesel engines or cause premature wear or damage to diesel engines. This must include but is not limited to data on lubricity, corrosion, and damage to engine parts such as fuel injector tips. The applicant must provide data showing under what temperature and conditions the candidate alternative diesel fuel remains stable and usable in California.

4 DISCUSSION

This section of the report includes a more detailed discussion of the proposal and the reasoning staff used in developing the proposal.

4.1 Categorization of Diesel Emission Control Strategies

In developing the Diesel Risk Reduction Plan, staff originally envisioned a requirement that diesel emission control strategies achieve a PM emission rate of 0.01 grams per brake horsepower-hour level (g/bhp-hr), or an 85 percent or greater PM reduction. These levels were determined based on the performance of catalyzed passive diesel particulate filters (DPFs). However, subsequent investigation and field trials have indicated that passive DPFs do not work with some applications and engines. For instance, most two-stroke diesel engines (common in transit buses) have exhaust that is too cold and dirty for current passive DPF designs. Lower levels of PM reduction have been repeatedly demonstrated in the U.S. with other technologies, however, such as diesel oxidation catalysts (DOCs). Results vary, but DOCs are typically capable of reducing PM by 25 percent on a mass basis. ARB faces the challenge of reducing PM emissions from virtually all diesel engines in on-road, off-road, and stationary applications, but the only high-efficiency control strategy proven out so far in the U.S. has limited application. In recognition of this, and in order to facilitate the implementation of emission control strategies, ARB has incorporated a multi-level verification system in the verification procedure.

The multi-level verification system consists of three PM reduction levels as shown in Table 7. Adoption of this system should broaden both the spectrum of control technologies available to participate in California's diesel emission control effort and the number of applications that can be controlled. Having opened the door to other strategies for reducing diesel PM, DOCs, for instance, may find a role to play with the oldest, dirtiest engines still in use, giving a Level 1 PM reduction. Combinations of different strategies may also find appropriate applications, such as the use of DOCs together with water-emulsified fuel, which would most likely qualify as a Level 2 system. Both active and passive DPFs would qualify for Level 3 verifications, covering most of the cleaner applications in which neither oil consumption nor energy requirements for regeneration are excessive. It should be noted that, while staff is recommending a multi-level approach to verification, ARB is not deviating from the goal to achieve the maximum reductions in diesel PM emissions that is economically and technologically feasible.

Table 7. PM Verification Levels

Category	PM Reduction
Level 1	≥ 25 but < 50 percent
Level 2	≥ 50 but < 85 percent
Level 3	≥ 85 percent, or 0.01 g/bhp-hr

Although a multi-level approach has been selected for PM, only a minimum verifiable reduction has been chosen for NOx (refer back to Table 1). The primary reason for this distinction lies in the difference in nature of these two pollutants. In 1998, diesel PM was classified by ARB as a toxic air contaminant. Health effects from toxic air

contaminants may occur at extremely low levels of exposure, and it is typically difficult to identify levels that do not produce adverse health effects. A level-approach gives a hierarchical structure for PM-reducing technologies, within which higher levels naturally give connotations of being “better.” The primary concern with NOx is that it is an ozone precursor, and ambient air quality standards do exist for ozone.

4.2 Emission Control Groups

Experience with passive catalyzed DPFs led staff to better define ARB’s role in diesel emission control strategy verification. As described in Appendix B, diverse and highly application-specific factors play a role in determining the success or failure of a passive DPF in a given application. Staff’s initial thought was to verify systems by engine family, using the system developed for new engine certification. However, considering only new engine certification information is far from adequate to predict how a passive DPF will work with a given application. Any meaningful predictive effort is best left to the applicant because it requires duty cycle information on a vehicle-by-vehicle basis. ARB’s role is to determine if a given strategy’s emission reductions are real and durable, to establish the emission reduction level, to verify that the strategy has had successful field experience, and to investigate any secondary emissions of concern.

In order to evaluate a diverse set of diesel emission control strategies for use with a highly diverse in-use diesel fleet, ARB needs some way of categorizing diesel vehicles and equipment in a practical and flexible manner. Therefore, staff developed a new system that uses basic, control strategy-significant parameters of both the engine and application to create “emission control groups.” The parameters and their values depend on the nature of the strategy. This built-in flexibility is essential because ARB will evaluate quite diverse technologies with this single Procedure.

Table 8 below shows some sample parameters and values that may be used to determine the emission control groups for passive catalyzed DPFs used in on-road applications.

Table 8. Sample Parameters and Values for Passive DPFs in On-Road Applications

Parameters		Values			
Application	**Vehicle operation**	Higher speed, less stop-and-go		Lower speed, more stop-and-go	
	Intermittent Idling	Infrequent		Frequent	
	Fuel	≤ 15 ppmw sulfur	Standard		Other
Engine	**PM cert. level**	0.1	0.25	0.6	Unregulated
	Cycle	4-stroke		2-stroke	
	Aspiration	Turbocharged		Natural	
	EGR	With		Without	

One emission control group for on-road applications, for example, would be all lower-speed vehicles with significant stop-and-go operation, fueled with standard diesel fuel, and powered by turbocharged, four-stroke diesel engines originally certified to the 0.25 g/bhp-hr PM standard. This emission control group would include some number of buses and refuse haulers, for instance. An example of what one emission control group might look like for stationary applications is shown in Table 9. Emission control groups for other applications and dissimilar emission control strategies could differ, and will be determined by staff as necessary with input from applicants.

Table 9. Example of an Emission Control Group for Passive DPFs in a Stationary Application

Application Parameters	**Example Values**
Uses	Emergency Standby Generator
Maximum Idle Hours per Day	4 hours
Minimum Load/Time Requirements for Regeneration	50% load for 30 minutes every 2 months
Exhaust Temperature range required for designed operation	250 – 400 degrees Celsius
Minimum Temperature Required to Maintain Over % of Hours of Operation	350 degrees Celsius over 20% of total hours of operation.
Maximum Idle % of Engine Operation	30%
Fuel	Low Sulfur CARB Diesel (<15 ppmw)
Engine Parameters	**Example Values**
Makes/Models	Manufacturer X, (models a thru z)
Engine Displacement	1500 cubic inches
PM Certification Level (test method)	0.06 g/bhp-hr (off-road certification test)
NOx Certification Level (test method)	6.9 g/bhp-hr (off-road certification test)
Cycle	4-stroke
Horsepower	1200 bhp
Maximum Backpressure Specifications	30 inches of H20
Aspiration	Turbocharged

Because the verification procedure is to be used for a wide range of technologies, each with its own nature, strengths and weaknesses, applicant input is important. In the early stages of the application process, the applicant is encouraged to assist staff in determining a set of parameters appropriate for its diesel emission control strategy. This coordination with staff will help identify appropriate use of any existing data and potentially reduce the amount of testing that would be required under an engine family based system.

Emission control groups are fully integrated into the verification procedure for both initial verifications and extensions of existing verifications. For the initial verification of a diesel emission control strategy, the applicant must restrict its application to a single emission control group. By requiring that the scope of the first application be thus restricted, staff will be more able to conduct a thorough review of the diesel emission control strategy. Extensions of existing verifications need not be limited to a single emission control group, but are nevertheless made on an emission control group basis.

4.3 Initial Verification Requirements

For a diesel emission control strategy to be verified, it must fulfill testing and informational requirements discussed below. Responsibilities of an applicant after its strategy is verified are discussed in section 4.4.

4.3.1 Emission Testing

The primary aim of emission testing is to ensure that diesel emission control strategies give real emission reductions without generation of harmful secondary emissions.

4.3.1.1 Test Engine/Vehicle

The applicant may select the engine(s) or engine/vehicle combination(s) it wishes to test, provided that the selection is within the emission control group chosen for verification. It may be to the applicant's advantage to test engines within the emission control group that are considered "worst case" for the particular diesel emission control strategy being tested in that doing so could assist the applicant's engineering justification that the strategy is appropriate for use with another emission control group. If, for instance, the emission control group being applied for includes 1994-2001 model year on-road engines, successful testing with a higher-emitting 1994 engine with a sub-standard maintenance history may make a stronger case for extending a verification to 1991-1993 engines than had a 2001 engine been tested.

4.3.1.2 Test Fuel

There are a number of considerations for the applicant to make when selecting the test fuel:

- The test fuel must meet California's diesel fuel specifications described in Sections 2280-2283, Title 13 of the California Code of Regulations, with the exception of sulfur content and any other properties identified by the applicant and approved by staff.
- If operation or performance of a diesel emission control strategy is affected by fuel sulfur content, the sulfur content of the test fuel must be no less than 66 percent of the stated maximum sulfur content for the diesel emission control strategy, unless
  - (A) the testing is performed with fuel containing 15 ppmw or less sulfur for verification on 15 ppmw or less sulfur diesel fuel, or
  - (B) the testing is performed with diesel fuel commercially available in California for verification on CARB diesel fuel.

Unless fuel modifications are part of the diesel emission control strategy, baseline testing must be conducted with the same fuel used in control tests. This requirement separates any emission reductions associated with changes in fuel composition from those achieved by the diesel emission control strategy.

If the diesel emission control strategy requires a specific fuel (e.g. fuel with 15 ppmw or less sulfur is needed for some catalyzed filters), testing must be conducted using that fuel. If there are any differences between this fuel and commercial California diesel fuel, the applicant must indicate what they are. These differences will define, in part, the emission control group for which the strategy is verified. It should be noted that 15 ppmw or less sulfur fuel is now the standard for California transit buses as of July, 2001, and will be required nationwide in 2006.

Regardless of the fuel used, the test fuel (or batch of fuel purchased) must be analyzed using American Society for Testing and Materials (ASTM) test methods (see Appendix A). At a minimum, the fuel's content of sulfur, aromatics, polycyclic aromatic hydrocarbons, and nitrogen, and the cetane number must be measured and reported. ARB may ask for additional properties to be reported if evidence suggests those properties may affect functioning of the diesel emission control strategy.

4.3.1.3 Test Cycle

Table 2, below, indicates which test cycles the applicant must use to verify a diesel emission control strategy's emission reductions. In testing for on-road emission control groups only, the applicant may choose between engine and chassis dynamometer-based testing. Note that the emission test data may be used as the initial durability test data as well, but that the same test method and cycle must be used in the final durability test for consistency.

Table 2. Test Cycles for Emission Reduction Testing*

Test Type	On-Road	Off-Road (including portable engines)	Stationary
Engine	FTP Heavy-duty Transient Cycle (1 cold-start and 3 hot-starts)	Steady-state test cycle from ARB off-road regulations (3 hot-starts)	Steady-state test cycle from ARB off-road regulations (3 hot-starts)
Chassis	Heavy-duty UDDS (1 cold-start and 3 hot-starts) and another ARB approved test cycle as described below (3 hot-starts)	Not Applicable	Not Applicable

* Additional hot-starts are required for NOx emission reduction between 15 to 25 percent (see section 2703 (h).
FTP = Federal Test Procedure
UDDS = Urban Dynamometer Driving Schedule

Chassis dynamometer testing for on-road applications requires two test cycles: the Urban Dynamometer Driving Schedule (UDDS) for heavy-duty vehicles, which is a common test cycle that replicates the FTP test cycle , and a lower-speed cycle with events of maximum vehicle acceleration from intermittent idle periods, such as the New York Bus Cycle (NYBC). Out of all the chassis test cycles available, these two types were selected so that a wide range of on-road operation, from freeway conditions to urban stop-and-go, would be covered. The applicant's choice of low-speed chassis test cycle must be approved by staff, and staff will provide suggested cycles at the applicant's request. The engine dynamometer testing option only requires one test cycle, the FTP, because no stop-and-go type engine cycle exists at this time. However, since new engine certification is conducted using the FTP cycle, a greater body of knowledge is available to draw upon.

For NOx emission reductions only, ARB has established a minimum reduction that it will verify of 15 percent relative to the baseline. For reductions that are 25 percent and greater, the testing thus far described is sufficient. For reductions between 15 and 25 percent, additional testing is required to ensure an accurate determination of the reduction in the face of test-to-test variability. The number of hot-start test runs must be increased to five for NOx reductions between 20 and 25 percent, and nine for reductions between 15 and 20 percent (see Appendix D for the statistical determination of these additional test runs). Consider a diesel emission control strategy that reduces NOx between 15 and 20 percent. If chassis testing is selected, for example, one cold and nine hot-start UDDS and nine hot-start low-speed cycle tests are required. Similarly, durability testing requires one cold and nine hot-start tests.

For any diesel emission control strategy which is designed to reduce NOx emissions from on-road engines, additional testing beyond that specified in Table 2 is required. This requirement arises because many engine manufacturers incorporated "defeat devices" into electronically-controlled on-road heavy-duty diesel engines. During certification testing, these engines meet NOx standards. During "off-cycle" highway operation, however, the defeat device alters engine operation to be more efficient but results in NOx emissions far above the standard. To verify reductions in NOx emissions from on-road engines, therefore, the applicant must test its strategy using an additional test cycle (proposed by the applicant and approved by ARB) that will trigger any form of defeat device. Staff will evaluate the proposed test cycle based on its representativeness of real-life operation and consistency with established procedures for determining off-cycle emissions. The European Stationary Cycle, which will be a required test cycle for engine certification, may not be adequate for the purposes of this Procedure, given the general lack of knowledge at this time concerning parameters that trigger defeat devices.

In October 1998, ARB and U.S. EPA reached court settlements with the engine manufacturers that had used defeat devices. The resulting consent decree had a number of requirements for the manufacturers to fulfill. Although the Procedure can be used to evaluate NOx reductions, staff emphasizes that a verification in no way

indicates a determination that a diesel emission control strategy satisfies any of the requirements set forth in the consent decrees.

For both off-road and stationary applications, the applicant must choose a steady-state test cycle and method indicated in the ARB off-road regulations (California Code of Regulations, Title 13, Section 2423 and the incorporated California Exhaust Emission Standards and Test Procedures for New 2000 and Later Off-Road Compression-Ignition Engines, Part I-B). The applicant must choose the most representative off-road test cycle for the emission control group for which it seeks verification.

The applicant may request staff to approve an alternative test cycle to those listed in Table 2 if the need arises. Some of the criteria staff will use in evaluating a proposed alternative are:

- Similarity of average speed, percent of time at idle, average acceleration, and other characteristics to the specified test cycle or method,
- Body of existing test data generated using the alternative test cycle or method,
- Technological necessity, and
- Technical ability to conduct the required test.

4.3.1.4 Test Run

The number of baseline test runs (i.e., without the diesel emission control strategy implemented) must equal the number of control test runs. Also, for filter-based strategies, both the engine backpressure and exhaust temperature must be measured and recorded on a second-by-second basis for at least one baseline run and for all of the control test runs. This information will assist staff in understanding what goes on inside the “black box” as the test cycle progresses.

4.3.1.5 Emissions During Regeneration Events

As noted in Appendix B of this report, some diesel emission control strategies capture and store diesel PM and periodically burn it off using some external energy input. The verification procedure requires that emissions be measured during these regeneration events. If a regeneration event will not occur over the course of a given test cycle, applicants may pre-load the diesel emission control system with PM such that an event will occur within a test cycle. For any diesel emission control strategy that does not regenerate during normal operating conditions in the vehicle or equipment (for example, the filter is regenerated in an off-site oven), applicants must propose an appropriate method to measure the emissions at the regeneration event.

4.3.1.6 Exhaust Analyses

For all test runs, the applicant must report the emissions of total PM, non-methane hydrocarbons or total hydrocarbons (whichever is used for the relevant engine or vehicle certification), total NOx, NO_2, carbon monoxide and carbon dioxide.

In addition to the pollutants mentioned above, the Executive Officer may require that the applicant perform additional exhaust analyses if there is reason to believe that the use of a diesel emission control strategy may result in the increase of toxic air contaminants, other harmful compounds, or a change in the nature of the emitted PM. The verification procedure is intended to verify emission reductions from an extremely diverse range of technologies, ranging from DPFs to alternative diesel fuels, that may have unforeseen side-effects on diesel emissions. Some forms of catalysis used in passive DPFs have already been shown to significantly increase the NO_2 fraction of NOx emissions. Therefore, staff deems it essential that additional analyses be required as necessary. The following criteria form the basis for ARB's determination if any additional analyses are required:

- The nature of any substance added to the fuel, intake air, or exhaust stream,
- Whether a catalytic reaction is known or reasonably suspected to increase toxic air contaminants or ozone precursors,
- Results from scientific literature,
- Field experience, and
- Any additional data.

Additional analyses may include, but are not limited to, measurement of benzene, 1,3-butadiene, formaldehyde, acetaldehyde, polycyclic aromatic hydrocarbons (PAH), nitro-PAHs, dioxins, and furans.

4.3.1.7 ARB Presence During Testing

For any diesel emission control strategy sold, offered for sale, or manufactured for sale in California, ARB may require the applicant to make available for testing and/or inspection a reasonable number of units, and direct that they be delivered to a location specified by ARB. Furthermore, ARB may have an applicant test and/or inspect a reasonable number of units at the applicant or manufacturer's facility or at any test laboratory under the supervision of ARB staff. These powers are consistent with existing regulations for new engines.

4.3.2 Durability Testing

The previous section on emission testing described how ARB intends to verify emission reductions for diesel emission control strategies. This section focuses on the procedure for verifying that a strategy's emission reductions are durable. The applicant may choose to perform either an actual field demonstration or a laboratory-based demonstration. In either case, the emission tests must be conducted at the beginning and end of durability period to investigate the performance of the diesel emission control strategy over time. If the applicant opts for a laboratory-based durability demonstration, it must then demonstrate in-field compatibility as described in Section 4.3.3 of this report. If the applicant has demonstrated durability for the identical system in a prior verification or has demonstrated durability through field experience, the applicant may

request ARB to accept the previous demonstration. In evaluating such a request, staff will consider relevant information including, but not limited to:

- Similarity of baseline emissions and application duty cycles,
- The relationship between the emission control group used in previous testing and the current emission control group,
- Number of engines tested,
- Evidence of successful operation and user acceptance, and
- Published reports.

4.3.2.1 Engine Selection

Subject to ARB approval, the applicant may choose the engine and application to be used in the durability demonstration. The engine and application must be representative of the emission control group for which verification is sought. The selected engine need not be the same as the engine used for emission reduction testing, but if the applicant does use the same engine, the emission reduction testing can also be used for the initial durability tests.

4.3.2.2 Service Accumulation

Staff had originally envisioned requiring durability demonstrations as great as 150,000 miles for heavy-heavy duty vehicles, in order to reflect the long lifetimes of most diesel engines. However, engine manufacturers and emission control device manufacturers have commented that such periods were too great and posed a large barrier to getting diesel emission control strategies verified. At the same time, representatives for the end-users have indicated that such periods were small compared to the mileage accumulated by many heavy-duty vehicles on the highway. Nevertheless, ARB does recognize the significant amount of both time and money required to meet the originally proposed service accumulation periods, in particular the burden it places on small manufacturers. Because of these concerns, and to be more consistent with new engine certification requirements, staff proposes a durability demonstration of 50,000 miles or 1000 hours for on-road applications, and 1000 hours for off-road applications. As stationary emergency generators typically experience less sustained operation, staff proposes a 500 hour durability period for that equipment (see Table 4).

Table 4. Minimum Durability Demonstration Periods

Engine Type	Minimum Service Accumulation
On-Road	50,000 miles or 1000 hours
Off-Road (including portable engines) and Stationary	1000 hours
Stationary emergency generator	500 hours

For in-field service accumulation, the application selected must be representative of the engines and applications of the emission control group for which verification is sought. For service accumulation in the laboratory, the applicant must propose a duty cycle approved by staff. The duty cycle should be representative of operation of the engine/vehicle in the field. Staff envisions most applicants selecting a "worst case" member of the emission control group to facilitate subsequent extensions of the initial verification.

4.3.2.3 Emission Testing for the Durability Demonstration

The staff proposes that emissions testing be conducted as part of the durability demonstration. This testing would provide further certainty that the emissions control strategy was durable both physically and in functionality.

Table 5 shows the emission testing required during the durability demonstration. The diesel emission control strategy must be tested a minimum of twice over the course of the durability demonstration period: once at the beginning and once at the end. Baseline testing is required only once, either before the initial test of the emission control strategy, or following the final test of the emission control strategy. The tests are intended to provide a picture of how the performance of a diesel emission control strategy may change over time. If there are substantial test data from previous field studies or field demonstrations, applicants may request the ARB to waive the initial emission tests. As described for emission testing, engine backpressure and exhaust temperature upstream of a filter-based diesel emission control system must be measured and recorded over the entire durability test. The measurements must be recorded at time intervals not to exceed two minutes over the entire durability demonstration period. This data-logging is helpful for indicating the frequency of regeneration, and providing a greater understanding of the diesel emission control system.

Table 5. Emission Tests Required for the Durability Demonstration

Application	Test Type	Test 1 (0% of durability period)	Test 2 (100% of durability period)
On-Road	Engine	FTP Heavy-duty Transient Cycle (1 cold and 3 hot-starts)	
	Chassis	UDDS (1 cold and 3 hot-starts) and an ARB approved low-speed test cycle (3 hot-starts)	
Off-Road and portable engines	Engine	Steady-state test cycle from ARB off-road regulations or an alternative cycle (3 hot-starts)	
Stationary	Engine	Steady-state test cycle from ARB off-road regulations or an alternative cycle (3 hot-starts)	

For on-road applications, the testing depends on the nature of the service accumulation. If an in-field demonstration is selected, the applicant would typically perform chassis dynamometer testing, unless staff approves a request to consider engine dynamometer testing. In reviewing such a request, staff will consider the following: (1) similarity of the field vehicle's engine to the laboratory engine, and (2) similarity of the diesel emission control system's calibration and set-up when installed on the field vehicle to that when installed on the laboratory engine. While staff does not encourage this approach, it does recognize both the limitations on the number of heavy-duty chassis dynamometers available and also the fact that some diesel emission control systems are sufficiently simple that they can still be satisfactorily evaluated on a different engine. As shown above in Table 5, the applicant must use the same cycles and emission testing procedure as described in Section 4.3.1.

For off-road and stationary applications, the applicant must use the same cycle it chooses for emission testing as described in Section 4.3.1. Similarly, a minimum of three hot-start tests is required.

4.3.2.4 Maintenance

Except for emergency engine repairs, only scheduled maintenance on the engine and diesel emission control system may be performed during the durability demonstration. If normal maintenance includes replacement of any component of the diesel emission control system, a description of the maintenance, including the time (miles, years, or hours) between component change or re-fill must be included with the results of the demonstration. This includes the re-fill of any form of fuel additives stored on-board.

4.3.2.5 Performance Requirements

Throughout the durability demonstration period, the diesel emission control strategy must meet the following requirements:

(1) If the applicant claims a percent emission reduction, the percent emission reduction must meet or exceed the initial verified percent emission reduction level.
(2) If the applicant claims to achieve 0.01 g/bhp-hr, the emission level must not exceed the 0.01 g/bhp-hr emission level.
(3) The diesel emission control system must maintain its physical integrity. Its physical structure and all of its components not specified for regular replacement during the durability demonstration period must remain intact and fully functional.
(4) The diesel emission control strategy must not cause any damage to the engine.
(5) The backpressure caused by the diesel emission control strategy should not exceed the engine manufacturer's specified limits, or must not result in any damage to the engine.
(6) No maintenance of the diesel emission control system beyond that specified in its owner's manual will be allowed without prior ARB approval.

4.3.2.6 Failure to Maintain Emission Reduction Performance

If the diesel emission control strategy does not maintain its initial emission reduction over the durability period for any reason, staff may downgrade the system to the verification level corresponding to the degraded performance, as determined by emission test results. If the diesel emission control strategy fails to maintain at least a 25 percent PM reduction or 15 percent NOx reduction (if applicable), it will not be verified. If the strategy fails, the applicant must submit a report explaining the circumstances of the failure within 90 days of the event. ARB will then determine if the applicant should continue the durability demonstration after fixing the failed system or begin a new durability demonstration.

4.3.2.7 Conditional Verification for Off-Road and Stationary Applications

In light of the small market share of diesel emission control strategies for highly diverse off-road and stationary applications, facilitating an early introduction of those strategies would provide economic incentives for manufacturers to pursue these markets. To encourage the development of such strategies, staff proposes to allow conditional verification for off-road and stationary applications.

If ARB is convinced that a diesel emission control strategy is technologically sound and appropriate for the intended application, a conditional verification may be granted upon completion of 33 percent of the minimum durability period. ARB may consider all relevant information including, but not limited to, the design of the diesel emission control system, similarity to already verified systems, the intended application, status with other verification programs (e.g., the U.S. EPA's Environmental Technology Verification Program and the Swiss VERT program), other relevant test data, and field

experience. Full verification is contingent on completion of the durability testing and submission of test results. These results must be submitted within a year after receiving conditional verification if laboratory testing is chosen and within three years if field-testing is chosen.

Staff continues to hold the viewpoint that the end-users of any verified device must have certainty that they are in compliance with any regulations. A successful diesel emission control strategy implementation program cannot be based on the state requiring installation of or providing incentives for devices that do not meet the minimum standards established. Therefore, staff has retained the provisions requiring replacement of any conditionally verified system that proves not to meet the requirements of full verification. In this way, manufacturers do have the ability to market products before final testing, but do so with the responsibility of ensuring that the end-users continue to meet the requirements of the diesel emission control strategy implementation program.

4.3.3 Field Demonstration

A field demonstration is not required for the purpose of determining in-field emission reductions, as it has no emission testing component. Instead, the purpose is to see if the diesel emission control strategy is compatible with the emission control group selected and how it stands up to real-world conditions. Compatibility here incorporates many aspects. It is important to determine, for instance, how much backpressure is imposed on the engine and if the operator notes any effects, how the system handles real-world vibrations, jolts, and variable exhaust flows, and what maintenance issues may turn up. The field demonstration, therefore, would verify that the applicant's system is technologically mature and ready for real-world application.

Compatibility is determined by ARB based on a third-party statement (described below) and any other data submitted including backpressure data in the case of filter-based strategies. A diesel emission control strategy will be considered compatible with the chosen application if it:

(A) Does not cause damage to the engine or engine malfunction,
(B) Does not generate backpressure outside of the engine manufacturer's specified limits or which does not result in any damage to the engine,
(C) Does not hinder or detract from the vehicle or equipment's ability to perform its normal functions, and
(D) Is physically intact and well mounted with no signs of leakage or other problems at the end of the demonstration period.

The applicant must demonstrate compatibility of its diesel emission control strategy in the field with at least one vehicle or engine belonging to the first emission control group it chooses for verification. ARB will consider existing field experience and engineering justification to determine whether additional emission control groups require separate

field demonstrations. If the durability demonstration selected is in-field, it may be used to satisfy the field demonstration requirement for that emission control group.

A vehicle or piece of equipment, with the exception of stationary emergency generators, must be operated with the diesel emission control strategy installed or implemented for a minimum of one-fifth of the durability demonstration period. The demonstration period is therefore 10,000 miles or 200 hours, whichever occurs first. For stationary emergency generators only, the period is defined as follows:

1) 12 maintenance runs (allowing for engine cool down between runs),
2) A minimum of two separate four hour sessions where the emergency generator is operated under load (allowing engine cool down between runs), and
3) A minimum in-field service accumulation of 30 days.

A written statement from an ARB-approved third party, such as the owner or operator of the vehicle or equipment used in the field demonstration, must be provided at the end of the test period. The statement must describe overall performance, maintenance required, problems encountered, and any other relevant comments. The results of a visual inspection conducted by the third party at the end of the demonstration period must also be described. The description should comment on whether the diesel emission control strategy is physically intact, securely mounted, leaking any fluids, and should include any other evaluative observations.

If the diesel emission control strategy fails in the course of the field demonstration, the applicant must submit a report explaining the circumstances of the failure within 90 days of the failure. ARB may then determine whether to deny verification or allow the applicant to correct the failed diesel emission control strategy and either continue the field demonstration or begin a new field demonstration.

4.3.4 Limit on Nitrogen Dioxide

Measurements of NO_X emissions (NO and NO_2) from heavy-duty diesel vehicles equipped with passive catalyzed filters have shown an increase in the NO_2 fraction, though total NO_X emissions remain approximately the same. Passive catalyzed filters oxidize NO to NO_2 which burns soot captured in the filter. More NO_2 is created than is actually used in the regeneration process; and the excess is emitted. In fact, the NO_2 to NO_X ratios could range from 20 to 70 percent, depending on factors such as the diesel particulate filter systems, sulfur level in diesel fuel, and the duty cycle (DaMassa, 2002).

At the February 6, 2002 International Diesel Retrofit Advisory Committee meeting, staff presented the results from updated modeling simulations for Southern California. The simulations were based on an assumed 90 percent market penetration of diesel particulate filters with varying NO_2/NOx ratios of 15, 20, 25, 30 and 50 percent. The results are presented in Table 10. The results of the study suggest that at an NO_2/NOx ratio of 20 percent (twice the baseline NO_2/NOx ratio of a diesel engine without a

passive catalyzed filter, used in the simulation), population exposure to ozone levels above the 1-hour State ozone standard would be reduced slightly. Simulated winter peak NO_2 would increase substantially, but remain well below the state ambient air quality standard, and both summer and fall $PM_{2.5}$ concentrations would decrease. The decrease in $PM_{2.5}$ occurs because the filter reduces carbon particles and hydrocarbon emissions. These reductions more than offset the increase in nitrates which are formed in the atmosphere because of the higher NO_2 emissions.

Table 10. Summary of Relative Percent Impacts from Simulated NO_2/NOx

Diesel NO_2/NOx		15%	20%	25%	30%	50%
Summer	24-hour O_3 Exposure > 90 ppb (%)	-3	-2	0	+2	+5
	Peak 24-Hour $PM_{2.5}$	-3	N/A*	N/A*	-2	-1
Fall	Peak 24-Hour $PM_{2.5}$	-6	N/A	N/A	-5	-3
Winter	Winter Peak 1-hr Exposure NO_2 (%)	+1	+6	+12	+18	+41

* N/A means the results were not available. However, the results can be estimated through interpolation of NO_2/NOx ratios between 15 and 30 percent.

Based on this study, staff proposes a cap of 20 percent of NO_2 to NOx emission ratio be established for all diesel emission control technologies. To ensure that the cap does not penalize retrofit strategies that reduce total NOx emissions, the 20 percent cap will be determined from the baseline (pre-control) emissions. Consider, for example, an engine that has total NOx emissions of 3.5 g/bhp-hr. A diesel emission control strategy that reduces total NOx by 40 percent would lower emissions to 2.1 g/bhp-hr NOx. If the post-control NO_2 level is at or below 0.7 g/bhp-hr, the system could receive verification. Although 0.7 g/bhp-hr is 33 percent of the controlled level, it is only 20 percent of the baseline level and therefore would comply with the staff's proposal.

The NO_2 emissions are measured by employing two chemiluminescence analyzers simultaneously fed from a common heated sample path. One instrument is set to NOx mode, while the second is set to NO mode. The instrument that is set to NOx mode receives a sample that has passed through an NO_2-to-NO converter, and the resultant concentration is designated as total NOx ($NO+NO_2$) in the sample. The instrument that is set to NO mode receives a sample that has not been passed through the converter and quantifies the amount of NO only. It is assumed that the difference between NO and NOx is the amount of NO_2 in the sample. A subtraction of NO from NOx is

performed on a second by second basis. The result of this subtraction is then integrated over the entire test run. The result of this integration is the amount of NO_2 over the entire test cycle in parts per million. The equation from the Code of Federal Regulations Subpart N, Part 86.1342-84 for calculating total NOx is then used to generate a gram per mile or g/bhp-hr NO_2 value.

4.3.5 Requirements for Fuel-Based Emission Control Strategies

Diesel emission control strategies which rely on fuel changes either through use of additives or through use of alternative diesel fuels must undergo an evaluation of the multimedia effects. Specifically, fuel based strategies must undergo review by the California Environmental Protection Agency Environmental Policy Council and comply with Health and Safety Code 43830.8 requiring testing of multimedia effects. The multimedia evaluation must also undergo peer review.

4.3.5.1 Fuel Additives

Fuel additives are essentially any substances added to the fuel. Additives can reduce the total mass of PM, with variable effects on CO, NOx and HC production. Use of some additives alone shows 15 percent to 50 percent mass reductions in PM. The reduction can be as high as 99 percent when used with a DPF. Some additive-based systems reduce polynuclear aromatic hydrocarbons by around 80 percent. A fuel borne catalyst (FBC) is a fuel additive containing one or more fuel-soluble metals, that acts as a catalyst to lower the temperature at which regeneration occurs within a diesel particulate filter. FBC can range from less than 10 ppm to greater than 100 ppm in the fuel. Mixed data exist regarding fuel economy. Some studies show a fuel economy improvement ranging from five to seven percent, while others show an equivalent fuel penalty. Most FBC are fairly insensitive to fuel sulfur content and will work with a range of sulfur concentrations as well as different fuels and other fuel additives (Mayer, 2000; DieselNet, 2000.02b).

FBC/diesel particulate filters systems are in widespread use in Europe for on-road, off-road, and stationary applications. Additives based on cerium, platinum, iron, and strontium are currently available, or may become available for use in the future. Past additives include those utilizing manganese, sodium, and copper and are not recommended for use due to the production of deleterious emissions, such as dioxins. See Appendix B for a description of the most common additives (Dieselnet, 2000.02b).

Although additives are promising with respect to reducing PM, either alone or in conjunction with a DPF, there are some potential drawbacks. Some formulations with high concentrations of metal can result in significant increased backpressure in DPF systems and/or filter plugging depending on the additives used (DieselNet, 2000.02b). The formulation concentration of the additive, as well as the actual base constituent of the additive will profoundly affect the behavior of the additive. Some studies show that

when used with a DPF, approximately one percent of metal consumed is emitted in the tailpipe exhaust (HEI, 1998).

Additionally, differences in concentrations of the FBC result in differences in PM emissions. In general, higher concentrations of additives also result in increased nano-particulate emissions. Studies show up to a 5-fold increase in the total number of solid particles and the formation of very small particles in the 20 nanometer (nm) to 40 nm range. This size fraction presents a health concern, as it is easily respirable and can penetrate deep into the lungs. The type of additive employed will also affect other characteristics of the emissions as well as the composition of secondary combustion by products. If part of a system, incorrect dosage may result in system failure and/or DPF damage or destruction (Mayer, 2000).

For most additives, copper being a marked exception, there is little evidence of acute toxicity risks. However, long term data regarding health risks and environment fate and transport are incomplete. Some additives might have potential to bioaccumulate and/or biotransform. Projections estimate soil cerium levels could double in the next few decades with air levels increasing by several orders of magnitude. Increased environmental platinum levels are documented in Europe since the widespread usage of catalytic converters (HEI, 2001; Ely et al, 2001).

As would be expected from a control strategy that introduces additional pollutants into the air, additives pose unique verification questions. The proposed procedure would allow the use of fuel additives, provided that certain precautions are taken. If used as part of a system, compatibility and durability must be addressed. Also, misfueling effects on the system and any incompatible products of fuel additives must be identified. Emission testing must include the additive alone in addition to the additive with other parts of the system, in order to provide sufficient information regarding the risks associated with use of the additive. Other precautions include the possibility of additional analyses, a periodic (2-year) review of relevant data, and an extremely strong recommendation that filters be used with any additive. Staff recognizes, however, that additives alone may have a place in achieving the over-all goals of the Diesel Risk Reduction Plan, if they can be determined to pose no threat to the environment or to human health.

Although some similarities exist, it is inappropriate to draw generalizations between additives. Even additives with similar “active ingredients” can have significant differences, so in evaluating additives, staff will draw generalizations between similar products, even from the same manufacturers, only after rigorous scientific and engineering reviews.

Finally, addition of the additive to the fuel can take one of three forms: dosing the bulk fuel, incorporation of an on-board dosing system in the vehicle, or allowing consumers to add the additive directly. The last alternative is discouraged as it allows for situations where the vehicle may run with an inappropriate additive dose. An on-board dosing system should include an onboard dosage system and monitoring systems. If the system includes a filter, filter backpressure monitoring and leak detection is necessary.

Any detected leak or filter failure should result in automatic termination of additive to the system. Manufacturers must address any special handling, cleaning and waste removal requirements due to the additive. In-use compliance testing must include verification that the correct dosage of additive is in the system and that all parts integral to the correct functioning of the system are in proper working order.

Staff's proposal requires emission testing of fuel borne catalyst systems at a dose of at least 50 ppm or ten times the dose rate stipulated for verification, whichever is greater. Testing at a higher dose than the strategy specifies is intended to identify any possible problems that might occur either due to misfueling or build up off the FBC in the system over time. Since testing at extremely high additive concentrations can result in filter plugging, staff has attempted to identify an appropriate level through review of existing data. Data exist from the VERT program (described in Section 7.2) for additive concentrations approaching 100 ppm. This data supports the concentration of 50 ppm as a useful level for determination of potential problems with an additive of any formulation. The 50 ppm dose should show any potential for filter plugging, sulfation, and changes in emission characteristics while preserving the ability to actually conduct meaningful testing.

If the higher dose would result in catastrophic damage to the engine, the applicant can petition to use less than 50 ppm. The applicant must supply information on failure modes, and the dose that triggers failure. The applicant must also supply information and data supporting the highest feasible dose for testing. An increase in emissions is not by itself sufficient to justify a dose lower than 50 ppm and must be correlated to potential engine damage. After reviewing information substantiating a lower dose, the Executive Officer would determine if testing at a lower level could be accepted, or if testing would need to be conducted at 50 ppm/ten times the specified dose rate.

4.3.5.2 Alternative Diesel Fuel Requirements

In addition to hardware-based technologies, staff proposes that the verification procedure also apply to diesel emission control strategies that involve “alternative diesel fuels.” For the purpose of this Procedure, alternative diesel fuels are fuels used in diesel engines that are not reformulated diesel fuels as defined in section 2281 and 2282 of Title 13, California Code of Regulations, and do not require engine or fuel system modifications for the engine to operate, although minor modifications (e.g., recalibration of the engine fuel control) may enhance performance. Examples include but are not limited to biodiesel fuels, Fischer Tropsch fuels, and water emulsified fuels. Natural gas is not an alternative diesel fuel. Both the definition just presented and the verification procedure are highly consistent with ARB’s existing Interim Procedure for Verification of Emission Reductions for Alternative Diesel Fuels (Nov. 3, 2000).

Applicants with control strategies that use an alternative diesel fuel formulation must follow the procedure detailed in the proposal, which includes durability testing on the whole system and a determination of any effects on the engine. However, data from the

Interim Procedure for Verification of Emission Reductions for Alternative Diesel Fuels (Nov. 3, 2000) can be used to meet some of the requirements.

The system will be verified on an emission control group basis, but engineering arguments may be used to extend verification to other emission control groups. Please note that fuels must go through U.S. EPA's registration process before they can be sold within the United States of America.

The applicant must initially submit a proposed test protocol to ARB. The test protocol must describe criteria pollutant and toxic emissions sampling and analyses that are consistent with the requirements of the Procedure, include a thorough description of the fuel, and indicate the specifications of the reference fuel to be used. ARB staff will work with the applicant as needed to develop an acceptable protocol. To ensure efficient use of resources, staff recommends that the applicant defer testing until ARB has approved the protocol. Upon completion of the tests, the applicant may submit an application for verification. The application must include the approved test protocol, all of the test data, the complete test log, a demonstration that the fuel meets the requirements of the Procedure, and other information that ARB may reasonably require.

The description of the candidate alternative diesel fuel included in the proposed test protocol must include the following:

(a) Identity, chemical composition, and concentration of fuel additives
(b) Sulfur content
(c) Total aromatic content
(d) Total polycyclic aromatic hydrocarbon content
(e) Nitrogen content
(f) API gravity (density)
(g) Distillation temperature distribution information, initial boiling point (IBP), 10% recovered (REC), 50% REC, 90% REC, and end point (EP)
(h) For emulsified fuels, include these descriptions of the base fuel, as well.

The applicant must also provide information on fuel properties that may affect engine performance, engine wear, and safety. Those properties include viscosity, volatility, and lubricity among others.

As the purpose of the Diesel Risk Reduction Plan is to reduce exposure to toxics, the applicant must also provide information on chemicals in the fuel that may increase levels of toxic compounds or potentially form toxic compounds in the fuel. The applicant must conduct an analysis for metals and other elements by a method specified by the applicant but subject to ARB approval. Copper, iron, cerium, lead, cadmium, chromium, and phosphorus must be included in the analysis. Additional analysis for other compounds may be required after staff reviews the chemical composition of the candidate alternative diesel fuel and its additives.

The applicant must also conduct comparative testing of the subject fuel and commercial California diesel fuel. The comparative emissions testing must be conducted by a party or parties that are mutually agreed upon by ARB and the applicant. The applicant is responsible for all costs of the testing.

Upon the applicant's completion of the above requirements, staff will evaluate the PM and NOx emission reductions as follows:

(A) PM. The average individual emissions of PM during testing with the candidate alternative diesel fuel must be specified as either 1) a percent reduction of the average emissions of PM during testing with reference fuel for levels 1, 2, or 3 verification, or 2) the average individual emissions of PM during testing with the candidate alternative diesel fuel shall be specified as a mass emission rate in g/bhp-hr if it is below 0.01 g/bhp-hr for level 3 verification.

(B) NOx. The average individual emissions of NOx during testing with the candidate alternative diesel fuel must be specified as a percent reduction of the average individual emissions of NOx, during testing with the reference fuel.

Note that other pollutant emissions must not increase by more than an amount consistent with test to test variability.

4.3.6 Other Requirements

In addition to the emission testing, durability testing, and field demonstration (if applicable), the applicant must meet a number of other requirements and provide additional information, much of which depends on the nature of the diesel emission control strategy.

4.3.6.1 Engine Backpressure and Monitoring

Throughout emission and durability testing, the applicant must demonstrate that the backpressure caused by its diesel emission control system is within the engine manufacturer's specified limits, or will not result in any damage to the engine. If backpressure will gradually increase over time (such as due to the accumulation of ash in a DPF), the applicant must describe how the backpressure is to be reduced in the application.

For all filter-based diesel emission control systems, a backpressure monitor must be installed to notify the operator of the vehicle or equipment when the backpressure limits, as specified by the engine manufacturers, are approached. At the discretion of ARB, the monitor should also be able to notify the operator when the backpressure has fallen below a lower limit which indicates that the filter medium has been breached. Such a monitor will provide valuable feedback to the operator as to the state of his or her filter system.

4.3.6.2 Fuel and Oil Requirements

The applicant must specify any fuel and lubricating oil requirements for proper functioning of the diesel emission control system. The applicant must also identify any consequences due to non-compliance with these requirements, as well as methods for reversing any negative side-effects.

4.3.6.3 Maintenance Requirements

The applicant must identify all standard maintenance requirements for the diesel emission control system. The applicant must specify the recommended intervals for cleaning and/or replacing components. Any components to be replaced within the warranty period must be included with the original diesel emission control system package or provided free of charge to the customer at the appropriate maintenance intervals. In addition, the applicant must specify procedures for proper handling and disposal of spent components and/or materials cleaned from the diesel emission control system. For filter-based diesel emission control strategies, the applicant must include procedures for resetting the backpressure monitor after maintenance procedures are completed.

4.3.6.4 System Labeling

The applicant must affix a legible and durable label on both the diesel emission control system and the engine on which the diesel emission control system is installed. This label must identify the name, address, and phone number of the manufacturer, the diesel emission control strategy family name (defined below), a unique serial number, and the month and year of manufacture. A scale drawing of a sample label must be submitted with the verification application. The label information must be in the following format:

Name, Address, and Phone Number of Manufacturer
Diesel Emission Control Strategy Family Name
Product Serial Number
ZZ-ZZ (Month and Year of manufacture, e.g., 06-02)

Each diesel emission control strategy shall be assigned a family name defined as below:

CA/MMM/YYYY/PM#/N##/APP/XXXXX

CA:	Designates a California approved diesel emission control system
MMM:	Manufacturer code (assigned by ARB)
YYYY:	Year of manufacture
PM#:	PM verification level 1, 2, or 3 (e.g., PM3 means a level 3 PM emission control system).

N##:	NOx verified reduction level in percent, if any (e.g., N25 means NOx reduction of 25 percent).
APP:	ON: On-road, OF: Off-road, ST: Stationary
XXXXX:	Five alphanumeric character code issued by the ARB

The purpose of the system label is to help the end-user to identify the type of diesel emission control systems that are installed on vehicles or equipment. Furthermore, it will assist the applicants to identify a representative sample of diesel emission control systems for in-use compliance testing. By using diesel emission control strategy family names, ARB will be able to clearly identify a given strategy and distinguish significant differences in design from superficial changes that are, for instance, employed by the applicant for marketing purposes.

4.3.6.5 Owner's Manual

The applicant must provide a copy of the owner's manual for the diesel emission control system, which must clearly specify at least the following information:

- Warranty statement including the warranty period over which the applicant is liable for any defects.
- Installation and maintenance requirements for the diesel emission control system.
- Possible backpressure range imposed on the engine.
- Fuel consumption penalty, if any.
- Fuel sulfur limit, if any.
- Handling and supply of additives, if any.
- Instructions for reading and resetting the backpressure monitor.
- Requirements for lubrication oil quality and maximum lubrication oil consumption rate.
- The applicant's contact information for replacement components and cleaning agents. "Contact your local distributor" is satisfactory.
- Contact information regarding the proper way to dispose of waste generated by the diesel emission control strategy (e.g., ash accumulated in filter-based systems). At a minimum, the owner's manual should indicate that disposal must be in accordance with all applicable Federal, State and local laws governing waste disposal, and when appropriate, hazardous waste disposal.

4.3.6.6 Noise Level Control

According to the Code of Federal Regulations, Part 205, Title 40, and California Vehicle Code Sections 27150, 27151, and 27200 through 27207, any diesel emission control system that replaces a muffler must continue to provide at a minimum the same level of exhaust noise attenuation as the muffler with which the vehicle was originally equipped by its manufacturer. Note that the California Highway Patrol is the state authority that enforces the noise level limits. Staff's proposal includes no specific test to check the noise level of vehicles equipped with diesel emission control systems. However, an applicant must attest that a diesel emission control strategy that replaces a muffler,

such as a DPF, complies with all applicable noise limits. Applicants must maintain a list of vehicles (make, model, engine, gross vehicle weight rating, and year of manufacture) for which the diesel emission control strategy is thus attested. Diesel emission control systems may only be installed on vehicles on that list.

4.3.7 Determination of Emission Reduction

ARB will verify emissions reductions for a diesel emission control strategy based on the average of all valid test results before (baseline) and after (control) implementation of the diesel emission control strategy. Test results from both emission testing and durability testing are to be used.

The percentage reduction for a given pair of baseline and control test sets (where a "set" consists of all test cycle repetitions, e.g., the test set of 1 cold and 3 hot-start UDDS tests) is the difference between the average baseline and average control emissions divided by the average baseline emissions, multiplied by 100 percent. The average of all such reductions, as shown in the equation below, is used in the verification of a diesel emission control strategy.

$$\text{Percentage Reduction} = 100\% \times \frac{\Sigma\,[(\text{baseline}_{AVG} - \text{control}_{AVG})/\text{baseline}_{AVG}]}{\text{Number of control test sets}}$$

Where:

Σ = sum over all control test sets

baseline_{AVG} or control_{AVG} = average of emissions from all baseline or control test repetitions within a given set

For any test set involving cold and hot starts, the time weighted emission result is to be calculated by weighting the cold-start emissions by one-seventh (1/7) and the hot-start emissions by six-sevenths (6/7) as shown below. If the applicant chooses not to do the final durability baseline test, it must use the initial durability baseline test results to calculate reductions for both the initial control and final control tests.

Weighted Emission Result = 1/7* average cold-start emissions + 6/7* average hot-start emissions

The absolute emission level is the average control emission level, as defined in the following equation:

$$\text{Absolute Emission Level} = \frac{\Sigma\,(\text{control}_{AVG})}{\text{Number of control test sets}}$$

4.4 Post-Verification Responsibilities

After a diesel emission control strategy has been verified for use with a given emission control group, it may be sold in California when verification is required, participate in numerous incentive programs in which verification is required, and may be used to satisfy the requirements of ARB in-use control regulations when and if they are adopted. After verification, applicants have the responsibility to perform in-use compliance testing and to honor the warranty.

4.4.1 Warranty

The applicant must provide a defects and performance warranty with a minimum coverage as shown in Table 6. During the warranty period, the applicant will be liable for any defects in the diesel emission control system, backpressure monitor (if applicable), and all hoses or connectors to the diesel emission control system, that present themselves in the course of normal operation. A defect may be structural, mechanical, or chemical in nature. In addition, a diesel emission control system will be considered defective if during the warranty period, emission control performance falls below the verified level.

Table 6. Minimum Warranty Periods

Engine Type	Engine Size	Minimum Warranty Period
On-Road	Light heavy-duty, generally 70 to 170 hp, GVWR normally less than 19,500 lbs.	5 years or 60,000 miles, whichever occurs first
	Medium heavy-duty, generally 170 to 250 hp, GVWR normally from 19,500 lbs. to 33,000 lbs.	5 years or 100,000 miles, whichever occurs first
	Heavy heavy-duty, generally exceeds 250 hp, GVWR normally exceeds 33,000 lbs.	5 years or 150,000 miles, whichever occurs first
Off-Road (includes portable engines) and Stationary	Under 25 hp, and for constant speed engines rated under 50 hp with rated speeds greater than or equal to 3,000 rpm	3 years or 1,600 hours, whichever occurs first
	At or above 25 hp and under 50 hp	4 years or 2,600 hours, whichever occurs first
	At or above 50 hp	5 years or 4,200 hours, whichever occurs first

4.4.1.1 Diesel Emission Control Strategy Warranty Report

The applicant must submit a warranty report to ARB by February 1 of each calendar year which includes the following information:

- Annual and cumulative sales of diesel emission control systems.
- Annual and cumulative production of diesel emission control systems.
- Annual summary of warranty claims. The summary must include:
  - A description of the nature of the claims and of the warranty replacements or repairs. The applicant must categorize warranty claims for each diesel emission control system model by the component(s) replaced or repaired.
  - The number and percentage of diesel emission control systems of each model for which a warranty replacement or repair was identified.
  - A short description of the diesel emission control system component that was replaced or repaired under warranty and the most likely reason for its failure.
- Date the warranty claims were filed and the engine family and application the diesel emission control systems were used with.
- Delineate the reason(s) for any instances in which warranty service is not provided to end-users that file warranty claims.

The staff's proposal would reserve the right for ARB to ask the applicant for additional testing if the warranty claims exceed two percent of the number of diesel engines using the diesel emission control strategy, or based on other relevant information.

Submitting all of the above information on a regular basis is one of the least costly methods for an applicant to provide data regarding the performance of a given diesel emission control strategy in the field.

4.4.2 In-Use Compliance

Staff is proposing to include an in-use compliance test program to ensure that the diesel emission control systems sold to end-users are as effective as those tested for verification (see Figure 1). Staff worked closely with U.S. EPA staff to harmonize the in-use compliance programs of the two agencies. The programs share a common statistical basis, and data collected for one program can be used to satisfy the requirements of the other.

In-use compliance testing is not required until at least 50 units of a specific diesel emission control strategy family have been sold in the California market. This is consistent with U.S. EPA's threshold of 500 units nationwide, since California possesses approximately 10 percent of the country's population.

Staff proposes that in-use compliance testing be conducted in two phases. For the first phase, the applicant would need to obtain and test diesel emission control systems within three months of their first maintenance, or after one year, whichever comes first. This early testing would allow ARB to identify and attempt to resolve any problems

associated with the diesel emission control systems before having widespread application of those systems in the market.

For each diesel emission control strategy family, an applicant is required to submit a proposal for obtaining the systems for approval by ARB prior to actual testing. The engines or vehicles using the selected diesel emission control systems must have good maintenance records and may receive a tune-up or proper maintenance prior to testing. The applicant must obtain information from the end users regarding the accumulated mileage or hours of usage, maintenance records, operating conditions, and a description of any unscheduled maintenance that may affect the emission results.

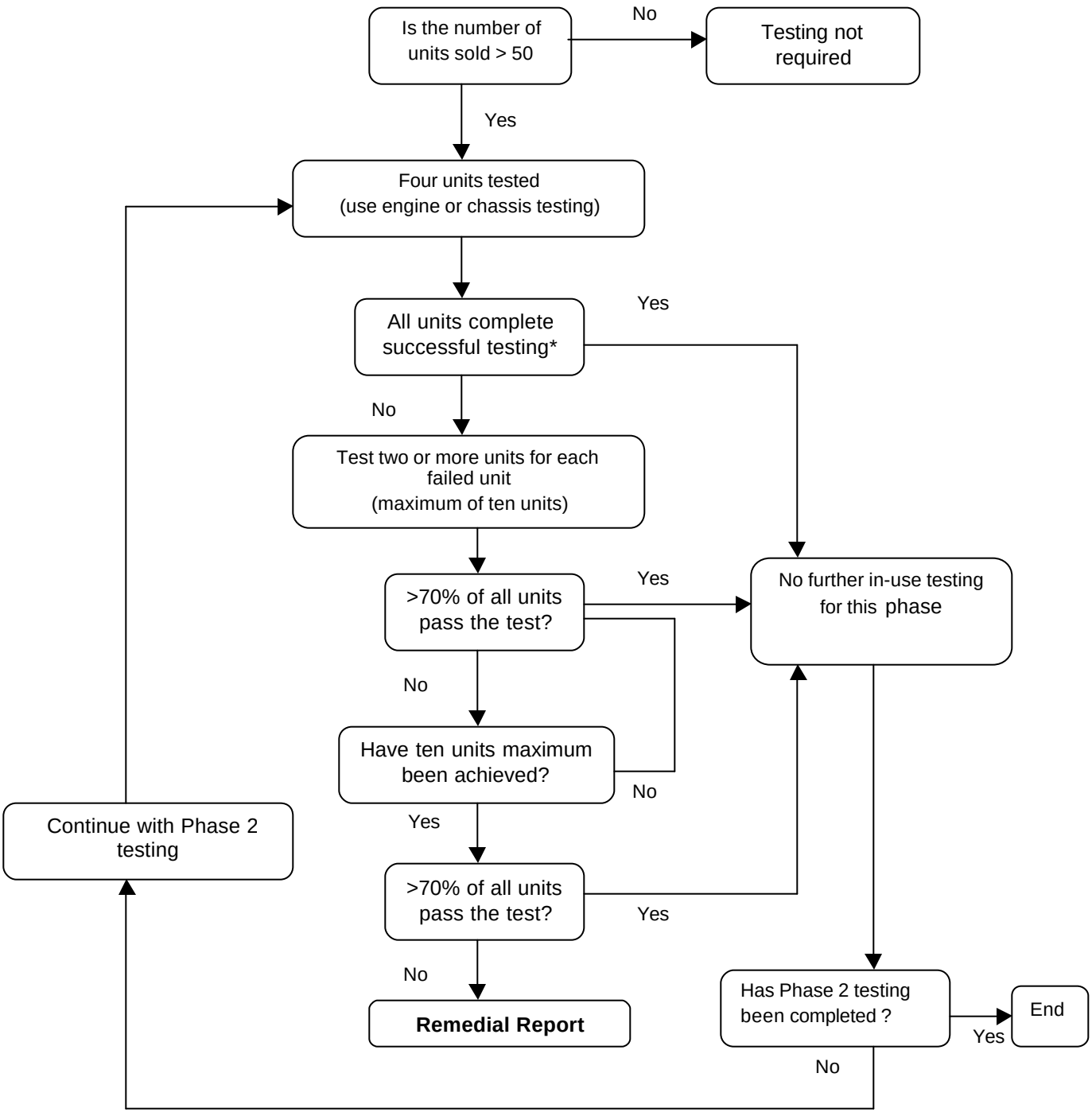
A minimum of four diesel emission control systems are to be obtained and tested. An applicant is required to follow the same testing procedure as used for emission testing for the initial verification, including the same test cycle(s) used originally. Doing so would eliminate any variations in emission reduction performance that occur with different test cycles. ARB could then make a more meaningful comparison of the emission reductions between the in-use diesel emission control strategies and those that were originally verified.

For each system tested that performs lower than 90 percent of the lower bound of its initial verification level (or above 0.011 g/bhp-hr PM for systems verified to an absolute level of 0.01 g/bhp-hr) two more systems must be tested. This process is to continue as necessary, until no more systems need to be tested, or until ten systems have been tested. This structure benefits the applicants whose systems perform consistently well. Not only will the applicants save money in the in-use compliance testing, it will also give them a competition edge over other diesel emission control systems that may not perform well under the in-use compliance testing program. At ARB's discretion, applicants may test more than the minimum of four diesel emission control systems or may concede failure before testing a total of ten diesel emission control systems. After all testing is completed for phase one, the applicant must submit an in-use compliance report that summarizes the results of in-use testing.

For the second phase of in-use compliance testing, the applicant must obtain and test diesel emission control systems which have been operated between 60 and 80 percent of their minimum warranty period. As in the first phase, the applicant must use the same test procedure and test cycles as were used for the original verification. Again, a minimum of four systems must be tested, and for each system that fails, two more systems must be tested. This process is to continue as necessary, until no more systems need to be tested, or until ten systems have been tested.

In the event that in-use compliance testing becomes overly burdensome to the applicant because of the structure or uniqueness of the industry in which the diesel emission control systems are used, the applicant may propose an alternative to the in-use compliance testing thus far described. The alternative must be a scientifically sound and reliable method to verify the emission reductions of the in-use diesel emission control systems.

Figure 1. ARB In-use Compliance Testing Requirements



*Note that a unit passes the in-use test (engine or chassis testing) if the emission reduction of the target pollutants (PM or NOx) are at least 90% of its verified reduction level. The diesel emission control systems tested at Phase 1 may differ from Phase 2. Both groups of diesel emission control systems must pass the in-use compliance testing to avoid cancellation of verification.

4.4.2.1 In-Use Compliance Report

The applicant must submit an in-use compliance report within three months of completion of each phase of the in-use compliance testing program. For each system tested, the following information must be reported:

- Parties involved in conducting the in-use compliance tests.
- Quality control and quality assurance information for the test equipment.
- Model and manufacture date of the diesel emission control system.
- Engine and vehicle or equipment the diesel emission control system was installed on.
- Estimated mileage or hours the diesel emission control system was in use.
- Results of all emission testing.
- Summary of all maintenance, adjustments, modifications, and repairs performed.

If a diesel emission control system failed catastrophically during the in-use compliance testing, the applicant would need to provide an investigative report detailing the causes of the failure to the Executive Officer within 90 days of the event.

4.4.2.2 Conditions for Passing the In-Use Compliance Program

For a diesel emission control strategy to pass compliance testing, emission test results must indicate emission reductions that are at least 90 percent of the initially verified emission reduction level. All four diesel emission control systems must pass the emission testing for full compliance. If there are failures and more units are tested, at least 70 percent of all units tested must pass. For each failed test, for which the cause of failure can be attributed to the product and not to maintenance or engine-related problems, two or more additional units must be tested, up to a total of ten units.

If the diesel emission control system fails the in-use compliance test, the applicant must submit a remedial report within 90 days after the in-use compliance report is submitted. The remedial report must include the following:

- Summary of the in-use compliance report.
- Detailed analysis of the failed diesel emission control systems and possible reasons for failure.
- Remedial measures to correct or replace failed diesel emission control systems as well as the rest of the in-use diesel emission control systems.

Staff proposes that the Executive Officer would evaluate the remedial report, annual warranty report, and all other relevant information to determine if the applicant has addressed all issues pertaining to the non-compliance of the diesel emission control strategy. Based on all relevant information, the Executive Officer may lower the emission reduction level or may revoke the verification all together.

4.4.2.3 ARB Presence During Testing

As in the context of emission testing, ARB may require the applicant to make available for compliance testing and/or inspection a reasonable number of units, and direct that they be delivered to a location specified by ARB. Furthermore, ARB may have an applicant compliance test and/or inspect a reasonable number of units at the applicant or manufacturer's facility or at any test laboratory under the supervision of an ARB Enforcement Officer. These powers are consistent with existing regulations for new engines.

5 INTERACTION WITH OTHER ARB DIESEL PROGRAMS

The Diesel Emission Control Strategy Verification Procedure is primarily intended to support the implementation of in-use control programs as discussed in the Diesel Risk Reduction Plan. However, it will also support several other programs designed to reduce NOx and PM emissions with in-use diesel controls. These programs include the following:

- Carl Moyer Memorial Air Quality Standards Attainment Program

  The Carl Moyer Memorial Air Quality Standards Attainment Program, approved in February 1999, is a grant program that funds the incremental cost of cleaner vehicles and equipment. This provides reductions in emissions of NOx through programs such as purchase of new vehicles or equipment; repower; and retrofit of in-use vehicles or equipment. More recently, the program has also set a goal to reduce PM. More information about the Carl Moyer program may be found at www.arb.ca.gov/msprog/moyer/moyer.htm

- Lower-Emissions School Bus Program

  The Lower-Emissions School Bus program is an incentive program to reduce the exposure of school children to both cancer-causing and smog-forming compounds. This program utilizes two strategies to attain these goals: 1) pre-1987 model year school bus replacement, and 2) in-use controls for other diesel-fueled school buses. More information can be found at www.arb.ca.gov/msprog/schoolbus/schoolbus.htm.

- Public Transit Bus Fleet Rule

  The public transit bus fleet rule, which is designed to achieve significant reductions in PM and NOx emissions from 2001 through 2015, includes an in-use emissions reduction component. The emission reductions could be achieved through the purchase of new low emission buses or repowering of older, higher-emitting busses to lower-emission configurations, in addition to equipping existing engines with emissions control systems. Additionally, some diesel emission control systems have already been verified for some bus engines. More information about the Public Transit Bus Fleet Rule may be found at www.arb.ca.gov/msprog/bus/bus.htm.

The Diesel Emission Control Strategy Verification Procedure provides a methodology that will enable these individual programs and rules to verify reductions in NOx and PM emissions. Specifically, most of these programs include provisions for an engine or vehicle owner to reduce emissions through in-use controls. Furthermore, each program has its own specific set of implementation criteria, such as targeted model year of vehicles and engines, testing procedures, reporting requirements, durability and NOx and PM emissions reductions. Thus, except for mostly minor program-specific variations, the Diesel Emission Control Strategy Verification Procedure provides a useful and timely strategy to assist the goals of the different implementation plans.

6 VEHICLE CODE 27156

Section 27156 of the California Vehicle Code addresses tampering of original equipment on a vehicle. In order to change original equipment with an aftermarket part, or add an "add-on" or modified part, an exemption to Vehicle Code 27156 must be obtained. This exemption is granted if the product has been determined not to cause any increase in vehicular emissions. However, this exemption does not address any emissions reductions due to the add-on part and therefore does not address the needs of the in-use control strategy market which is driven by the need to reduce particulate matter and NOx emissions.

During the interim phase of the Procedure, applicants have already been required to submit separate applications for the exemption of the Vehicle Code 27156 and the Procedure. However, the staff proposes that this Procedure would meet all the requirements for the VC27156 exemption. Thus, diesel emission control strategies verified by this Procedure would also be granted a VC27156 exemption simultaneously. In this way, only one Executive Order will be issued per diesel emission control strategy.

7 ISSUES OF CONTROVERSY

7.1 Harmonization with the U.S. EPA's Diesel Emission Control Strategy Verification Program

While both the staff's proposed Procedure and U.S. EPA's diesel emission control strategy verification programs share the common goal of verifying the emission reductions from diesel emission control systems, differences exist between these two programs. Both agencies have made tremendous efforts to harmonize the key requirements in both programs.

The proposed Diesel Emission Control Strategy Verification Procedure would apply to in-use strategies to control emissions of PM and NOx from on-road, off-road, and stationary sources. This Procedure would evaluate strategies that include but not limited to, diesel particulate filters, diesel oxidation catalysts, fuel additives, selective catalytic reduction systems, exhaust gas recirculation systems, and alternative diesel fuels.

The U.S. EPA's Voluntary Retrofit Verification Program is managed by the Office of Transportation and Air Quality while the Research Triangle Institute assisted in developing the draft General Verification Protocol for Diesel Exhaust Catalysts, Particulate Filters, and Engine Modification Control Technologies for Highway and Nonroad Use Diesel Engines, and oversees the testing projects (Research Triangle Institute, 2002). The U.S. EPA's draft General Verification Protocol applies to in-use strategies to control emissions of all pollutants from on-road and off-road sources only. Furthermore, the draft General Verification Protocol, still in its draft format, only evaluates the diesel oxidation catalyst, diesel particulate filter, and engine modification. Separate verification protocols will be developed for the NOx control technology (e.g., selective catalytic reduction system), alternative diesel fuels, fuel additives, and lubricants.

Table 11 compares the key elements of these two programs. In general, it should be noted that the staff's proposal is designed to support regulatory requirements while the U.S. EPA's retrofit program is voluntary. As outlined in the Diesel Risk Reduction Plan, ARB intends to reduce emissions in virtually all in-use diesel engines and equipment by 2010, through a number of diesel emission control strategy rules, targeting diesel-fueled engines from mobile and stationary sources at different timeframes. Thus, ARB has a greater burden to ensure those diesel emission control systems are indeed functional and durable.

In terms of verification threshold, staff's proposal categorizes the PM diesel emission control strategy systems into three levels; namely, level 1 (between 25 to 50 percent), level 2 (between 50 to 85 percent), and level 3 (over 85 percent or 0.01 g/bhp-hr). The minimum threshold for NOx is 15 percent and NOx is verified in 5 percent increments. For the U.S. EPA's draft General Verification Protocol, there is no minimum threshold for PM or NOx provided the emission reduction claim is verifiable and substantiated with a statistically estimated number of tests. The protocol requires that there should be sufficient number of tests at 95 percent confidence level to ensure that there will be a 90 percent probability of detecting the expected emission reductions. A third party testing facility will determine the emission reduction for the initial test and estimate the minimum of required tests using the actual emission reductions obtained.

Table 11. Comparison of the Diesel Emission Control Verification Program Between ARB and U.S. EPA

Verification Program Element	ARB	U.S. EPA
Operation	Retrofit Assessment Section of Mobile Source Control Division	Office of Transportation and Air Quality (OTAQ)
Program Nature	Regulatory	Voluntary
Program Goal	Verify diesel emission control systems capable to reduce at least 25% of PM and 15% of NOx	PM reduction
Application	On-road, off-road, and stationary sources	On-road and off-road sources
Verification Category	PM: Level 1: between 25 to 50% Level 2: between 50 to 85% Level3: between 85% or 0.01 g/bhp-hr NOx: at least 15%	HC, CO, NOx, and PM reduction will be assessed.
Diesel Emission Control Systems	Any retrofit technologies include but not limited to diesel particulate filters, diesel oxidation catalysts, selective catalytic reduction catalysts, fuel additives, alternative diesel fuels, or a combination of above	General verification protocol developed for diesel oxidation catalysts, diesel particulate filter, and engine modification. Other verification protocols will be developed for (1) selective catalytic reduction catalysts and (2) fuel additives and alternative diesel fuels.
Test Process	**On-Road** Engine Testing FTP Heavy-Duty Transient Cycle (1 cold and 3 hot-starts) Chassis Testing UDDS (1 cold and 3 hot-starts) and low speed, high idling cycle (3 hot starts) **Off-Road and Stationary** Engine Testing Appropriate off-road steady-state cycles (3 hot starts)	**Highway** Engine Testing FTP Heavy-Duty Transient Cycle (1 cold and 3 hot starts) **Non-Road** Engine Testing Specific steady state cycle for a particular engine classification
Backpressure Monitor	Required only for filter-based systems	Same as ARB
Minimum Durability Demonstration	On-Road: 50,000 miles or 1000 hours Off-Road and Stationary: 1000 hours Emergency generator: 24 hours Emission tests required at beginning and end of durability period. One baseline test is required.	Same as the minimum warranty period proposed by ARB. Durability tests required at 0% and 33% of the warranty period. Same durability period as ARB for heavy heavy-duty vehicles, but different durability period for medium, light heavy-duty vehicles. Different period durability for off-road engines/equipment.
Warranty	On-Road Light Heavy-Duty: 5 yrs/60,000 miles Medium Heavy-Duty: 5 yrs/100,000 miles Heavy Heavy-Duty: 4 yrs/150/000 miles Off-Road < 25 Hp: 3 yrs/1600 hrs 25 – 50 Hp: 4 yrs/2600 hrs >50 Hp: 5 yrs/4200 hrs	Warranty period defined by manufacturers
In-use Compliance Testing Program Nature Program Goal	Test four to ten diesel emission control systems at two phases, using engine or chassis testing. Phase 1 – first cleaning or end of first year, whichever comes first Phase 2 – between 60 to 80% of minimum warranty period Diesel emission control system must achieve at least 90% of original verified level to pass. At least 70% of all tested diesel emission control system must pass in order to be in compliance	Allow testing method other than chassis or engine testing such as the Real-time On-Road Vehicle Emission Reporter system.

Regarding the emission testing, the staff's proposal would allow chassis or engine dynamometer test while the U.S. EPA requires engine dynamometer test only. Hence, only data from an engine dynamometer test are acceptable by both programs. For instance, for on-road applications, both the staff's proposal and U.S. EPA require one cold and three hot-start of the Heavy-duty Transient Federal Test Procedure (FTP). Likewise, for off-road applications, applicants can submit the data from the engine dynamometer test to fulfil the emission test requirements for both agencies.

To ensure the diesel emission control systems are durable, staff's proposed Procedure requires a minimum durability demonstration period for diesel emission control strategy systems applicable to on-road, off-road, and stationary diesel engines or equipment. The durability demonstration can be conducted in the field or laboratory. Two durability tests are required during the course of the minimum durability period. The durability tests must be conducted at 0 percent and 100 percent of the required minimum durability period. However, baseline testing will be required only for the first or last durability test. On the contrary, the U.S. EPA proposes durability test only at the beginning (or 0 percent) and at 33 percent of the durability period established by the staff's proposal. Note that the EPA's minimum durability period is identical to the minimum warranty period proposed by the ARB. Thus, only diesel emission control systems for the heavy heavy-duty vehicle category will be tested for the same durability period as proposed by ARB while durability periods for medium heavy-duty, light heavy-duty, off-road, and stationary are different. Similar to the Procedure's durability requirement, the durability demonstration can be done in the field or laboratory. However, manufacturers need to conduct two baseline tests, at the beginning and the end of the durability period to fulfill the durability demonstration requirements. Finally, if all durability testing are conducted in the laboratory, staff's proposal would require field demonstration of 200 hours or 10,000 miles to ensure the system is indeed compatible in the field.

For warranty requirements, staff's proposal requires a minimum warranty period including specific warranty statements covering the physical integrity and emission requirements within the warranty period. However, the U.S. EPA's General Verification Protocol relies on the warranty information as defined by the manufacturers, and the warranty coverage could vary depending on the manufacturers.

After working closely to align the in-use compliance strategy, both ARB and U.S. EPA agree on the same in-use compliance program in general. One major difference is that the Procedure requires the applicants to conduct the tests consistent to the emission tests for which the diesel emission control system is verified; while the U.S. EPA allows testing methods other than those used for initial verification. Nevertheless, it is the goal of both agencies that manufacturers only need to conduct one in-use compliance program and meet all in-use compliance requirements as noted in Section 4.4.3.

Though both programs have been harmonized to the best extent possible, there are minor differences between these two programs. In general, the diesel emission system

that is verified by the U.S. EPA, can also be verified by the staff's proposal provided the following conditions are met:

1. Emission tests by engine dynamometer
2. Require the same warranty period as the Procedure
3. Durability test must at least cover the durability period proposed by the Procedure.
4. Field demonstration (if all durability is conducted only in the laboratory)
5. Same engine testing throughout the in-use compliance test program.

Despite the different needs of the two programs, staff is still working with the U.S. EPA to minimize differences. Note that while the U.S. EPA 's draft General Verification Protocol has not been finalized yet. It is likely that the U.S. EPA will modify its protocol and adopt some of the regulatory languages from the staff's proposed Procedure if the Board adopts the staff's proposed Procedure. Thus, the effort of harmonization is still underway. To ensure maximum harmonization, an applicant should contact both agencies prior to conducting testing.

7.2 Harmonization with the VERT Program

The Verminderung der Emissionen von Realmaschinen im Tunnelbau (VERT) program was formed jointly by the Austrian Accident Insurance Agency, the Swiss Agency for the Environment, Forests, and Landscape, the Swiss National Accident Insurance Organization ("Swiss Environmental Protection Agency"), and the German Association of Construction Professionals since 1994. Its original mission was to curtail the emissions from diesel engines at tunnel sites. Through the years, the VERT program has developed a verification guideline, the Suitability Test, to ensure the particulate filters meet the required filtration requirements (Mayer A., 2002).

Table 12 provides a summary that lists the key elements of the VERT Suitability Test versus ARB's Diesel Emission Control Strategy. The VERT's Suitability Test evaluates filtration characteristics of particulate filters in terms of particulate mass and particulate count before and after the field deployment for 2000 hours. The VERT defines the removal efficiency of the particulate trap using both the elemental carbon mass and number count (10 to 500 nm). The VERT requires any new particulate filter to meet a minimum 90 percent removal efficiency for elemental carbon and 95 percent removal efficiency for number count. However, after the particulate filter has been in operation for more than 2000 hours, the required minimum removal efficiency for elemental carbon changes to 85 percent and number count removal efficiency drops to 90 percent.

Generally speaking, the VERT program requires a particulate filter system to include: (1) filter medium, (2) regeneration equipment, and (3) on-board diagnostic system to monitoring the backpressure of the particulate filter.

There are three parts in the Suitability Test. Both Part I and 3 require testing on a LIEBHERR 914 T/105 kW construction engine or equivalent; and the engine test cycle is based on four operating points according to ISO 8178 C1 as well as transient tests. Part 2 of the Suitability is simply a field demonstration of the particulate filter in a vehicle or equipment.

Part 1 requires the emission testing when the particulate filter is in new state, deposited state, and after regeneration. It also monitors the emissions during the regeneration, metered additive dosage, and the on-board diagnostics system. Several methodologies are used to measure the particle count and size distribution. In particular, the particle count is measured by the Scanning Mobility Particle Sizer in combination with the Thermodenuder, the size-specific particulate mass is measured by the Electrical Low Pressure Impactor, and the particle surface is measured by the NanoMet. Part 2 of the Suitability Test is a field demonstration of the particulate filter for a typical application in a vehicle or equipment. Data loggers will be installed placed to record temperature and backpressure during the field demonstration. Any problems associated with the breakdown or repair of the particulate filter as well as fuel and oil consumption will be recorded. At least two of the three particulate filters must survive field demonstration without any damage. Finally, one of the two survived filters must be used for Part 3 of the Suitability Test. Part 3 of the Suitability Test is simply a repeat of Part 1, with only half of the required tests.

For the staff's proposal, manufacturers have the option to test the diesel emission control systems on an engine or chassis dynamometer, with appropriate test cycles. There is no requirement that all tests should be conducted on a pre-selected engine. All pollutants (HC, CO, NOx, PM) are measured in terms of mass only (g/mile or g/bhp-hr). However, if there are reasons for the Executive Officer to believe that the particulate filter may drastically increase the number of nanoparticles or other undesirable air toxics, the Procedure may require the manufacturers to conduct additional testing on particle size distribution or toxics. Regarding durability demonstration, the Procedure generally requires diesel emission control systems to be tested for 1000 hours or 50,000 miles in the laboratory or in the field. If all durability accumulation service is conducted in the laboratory, the diesel emission control system must be demonstrated in the field for at least 200 hours or 10,000 miles.

Similar to staff's proposal, if the particulate filter has catalytically active components suspected of forming secondary toxic emissions, then the polyaromatic hydrocarbon, nitro-polyaromatic hydrocarbon, and polychlorinated dibenzodioxins/furans (Isomers) must be monitored.

Table 12. Comparison of the Diesel Emission Control Verification Program Between ARB and VERT

Verification Program Element	ARB	VERT
Operation	Retrofit Assessment Section of Mobile Source Control Division	Swiss Agency for the Envrionment, Forests, and landscapte
Program Nature	Regulatory	Regulatory
Program Goal	Verify diesel emission control systems capable to reduce (1) at least 25% of PM and 15% of NOx	PM reduction in elemental carbon and number count (10 to 500 nm) Elemental Carbon count: 90% (new), 85% (after 2000 hrs) Number count (10 to 500 nm): 80% (new), 75% (after 2000 hrs)
Application	On-road, off-road, and stationary sources	On-road, off-road, and stationary sources
Verification Category	PM: Level 1: between 25 to 50% Level 2: between 50 to 85% Level3: between 85% or 0.01 g/bhp-hr NOx: at least 15%	Only PM reduction in terms of elemental carbon and number count.
Diesel Emission Control Systems	Any retrofit technologies include but not limited to diesel particulate filters, diesel oxidation catalysts, selective catalytic reduction catalysts, fuel additives, alternative diesel fuels, or a combination of above	Diesel particulate filter with active or passive regeneration process. May use fuel additives in combination with diesel particulate filter.
Test Process	**On-Road** Engine Testing FTP Heavy-Duty Transient Cycle (1 cold and 3 hot-starts) Chassis Testing UDDS (1 cold and 3 hot-starts) and low speed, high idling cycle (3 hot starts) **Off-Road and Stationary** Engine Testing Appropriate off-road steady-state cycles (3 hot starts)	**On-Road, Off-Road, and Stationary** Test Bed: 1989 Liebherr D914T/105 KW construction engine or Equivalent. Test Cycle: ISO 8178/4 C1 and transient cycle The following measurements are performed: 1. with/without filter 2. with/without fuel additives 3. Filter with new/loaded/regenerated/during regeneration
Backpressure Monitor	Required only for filter-based systems	Same as ARB
Minimum Durability Demonstration	On-Road: 50,000 miles or 1000 hours Off-Road and Stationary: 1000 hours Emergency generator: 500 hours	Repeat emission tests after 2000 hrs demonstration in the field.
Warranty	On-Road Light Heavy-Duty: 5 yrs/60,000 miles Medium Heavy-Duty: 5 yrs/100,000 miles Heavy Heavy-Duty: 4 yrs/150/000 miles Off-Road < 25 Hp: 3 yrs/1600 hrs 25 – 50 Hp: 4 yrs/2600 hrs >50 Hp: 5 yrs/4200 hrs	Minimum 2 years or 1000 hrs
In-use Compliance Testing Program Nature Program Goal	Test four to ten diesel emission control systems at two phases Phase 1 – first cleaning or end of first year, whichever comes first Phase 2 – between 60 to 80% of minimum warranty period Diesel emission control system must achieve at least 90% of original verified level to pass. At least 70% of all tested diesel emission control system must pass in order to be in compliance	Annual inspection of all diesel emission control system Using opacity test. Cutpoint for opacity is 10%. If > 5% of the diesel emission control systems fail the opacity test, may revoke the verification status.

Finally, the VERT requires that all diesel emission control strategy systems used in the field to be tested annually by using an opacity test (NanoMet). If more than 5 percent of the diesel emission control strategy systems exceeds a 10 percent opacity cutpoint, the diesel emission control strategy system may be removed from the verified list.
In short, major differences between the staff's proposal and the VERT's verification program can be summarized as follows:

1. PM reduction threshold
2. Diesel emission control strategies is limited to particulate filter and fuel additives
3. Test procedure and engine selection.
4. Warranty period
5. In-use compliance requirements

Nevertheless, staff's proposal is designed to take into account any emission and durability data for systems that have been verified under the VERT's program.

7.3 Warranty

Engine manufacturers have expressed concern that the proposed warranty period would be inappropriate. However, manufacturers of diesel emission control systems are confident that their systems can meet the proposed warranty period. Additionally, users have requested longer periods to match expected useful life. Staff believes that proposed periods are appropriate. For strategies employed on in-use diesel engines a shorter period would not provide sufficient consumer protection, while a longer period would add cost to the process that could hinder implementation. Successful implementation of in-use strategies will depend on user acceptance. Staff believes that the proposed warranty periods will foster this acceptance.

8 REGULATORY ALTERNATIVES

While developing the proposal, staff considered a number of regulatory alternatives, described below.

8.1 Do Not Require Verification

As outlined in the Diesel Risk Reduction Plan, ARB intends to reduce emissions in virtually all diesel-fueled engines and vehicles for minimizing the health risk associated with the diesel PM. Thus, it is critical that those diesel emission control strategy technologies meet a minimum emission reduction and durability requirement to ensure the emission reductions are real and the performance will endure.

Under the California Vehicle Code 27156, ARB allows the sale of an aftermarket part to be installed on a certified engine, provided that there is no net increase of any emissions associated with the installation of the aftermarket part. However, this provision of law does not require the quantification of emission reduction associated with the aftermarket part, if any. Currently, there is no regulation that verifies the emission reduction and durability claims for diesel emission control strategy technologies.

If the Diesel Emission Control Strategy Verification Procedure is not adopted, and no verification is available, there will be no guarantee that the diesel emission control systems are meeting the emission reduction and durability claims, as alleged by the manufacturers. In addition, end-users will not have the assurance that diesel emission control strategy technologies are compatible with a variety of diesel-fueled engines, under different operating circumstances. End-users will also be reluctant to invest in diesel emission control strategy technologies that may not have quantifiable emission reductions.

As a result, ARB would likely encounter tremendous resistance when diesel emission control strategy rules are proposed. Consequently, ARB will not be able to meet the Diesel Risk Reduction Plan goal of a 75 percent reduction in diesel PM and the associated cancer risk in 2010, and an 85 percent reduction in 2020. Furthermore, even were the rules adopted, ARB would not be able to gauge the success or failure of the program.

8.2 Rely on Other Verification Programs

Another alternative would be to rely on other verification programs, such as the U.S. EPA program or the VERT program. However, as noted in Section 7, these programs do not entirely coincide with the needs of the Diesel Risk Reduction Program. The U.S. EPA voluntary verification program at this time focuses only on diesel oxidation

catalysts, diesel particulate filters, and engine modifications and is limited to on-road and off-road application.

As described in detail in Section 7.1 above, the U.S. EPA's program is further limited in that only engine dynamometer testing is allowed, it does not cover stationary applications, and there are no minimum warranty requirements. Although the U.S. EPA program is well suited for the nationwide needs of voluntary retrofit programs, it would not be sufficient for meeting the overall goals of the Diesel Risk Reduction Plan.

Regarding the VERT program, it is limited to PM retrofit technologies with special emphasis on filters and fuel additives and does not include verification for the NOx emission control technologies. Furthermore, it specifies the filtration efficiency of particulate filters in terms of particle size and number instead of PM mass (which is the basis of ARB and U.S. EPA regulations), and requires less stringent 75 percent minimum efficiency.

9 ECONOMIC IMPACTS

The proposed Diesel Emission Control Strategy Verification Procedure simply establishes a protocol for evaluation of in-use diesel emission control technologies. Participation in the Diesel Emission Control Strategy Verification program is optional and presumably a business would use the Verification Procedure only if the business believes it will be financially advantageous for it to do so. Thus, there are no mandated costs to equipment manufacturers. Costs to these parties are incurred only if they choose to participate in the Program.

Costs to the manufacturers include research and development costs, marketing costs, and costs associated with the testing necessary to comply with the Diesel Emission Control Verification procedural requirements.

It must be noted that the program does not levy any requirements on end users. Costs to the end-users include purchase price and related expenditures and maintenance costs. Those costs will vary by market segment and will be addressed in detail as staff prepares the individual implementation proposals

9.1 Legal Requirement

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination or creation, and the ability of California business to compete with business in other states.

State agencies are also required to estimate the cost or savings to any State or local agency and school district in accordance with instructions adopted by the Department of

Finance. The estimate shall include and nondiscretionary cost or saving to the local agencies and the cost or saving in federal funding to the State.

9.2 Affected Businesses

Participation in the Program is not mandatory. However, any business or individual that chooses to participate in the Program will have to follow the Verification Procedure. Businesses that choose to participate and which would be subject to the Verification Procedure include those that manufacture or market diesel emission control technologies. Also, potentially indirectly affected are businesses that supply raw materials or equipment to these manufacturers or marketers, or distribute, sell or service these products.

9.3 Potential Impact on California Businesses

Should a manufacturer or marketer elect to participate in the verification program, it would need to provide detailed information and data on the product in accordance with the Procedure. The testing required by the Verification Procedure will possibly require significant expenditures of capital on the part of a company. The cost to perform all necessary tests depends on the engine type being verified as well as the type of testing performed (see cost estimate in Section 9.8, below). However, once the product is verified, it will be recognized as an option for meeting the goals of the Diesel Risk Reduction Plan.

Should a manufacturer choose not to participate in the Program, avenues exist allowing for the sale of the emission control system in California. As noted in Section 6, a manufacturer or marketer having an exemption from Vehicle Code 27156 can sell the product in California. However, this product would not be a verified emission control device, and would not be recognized.

The same requirements will hold for any manufacturer that wishes to sell their product in California, regardless of business location.

9.4 Potential Impact on Employment

The proposed Procedure is not expected to cause a noticeable change in California employment and payroll. Participation in the program is voluntary and presumably only businesses able to afford the program will participate.

9.5 Potential Impact of Business Creation, Elimination or Expansion

The proposed Procedure will have no noticeable impact on the status of California business. California businesses that supply monitoring equipment or testing facilities may benefit from increased industry spending on certification testing necessary to comply with the Program's requirements. Furthermore, some diesel emission control strategy companies may be created as a result of the proposed Procedure.

9.6 Potential Impact on Business Competitiveness

The proposed Procedure would have no significant impact on the ability of California's businesses to compete with businesses in other states. Participation on the program is voluntary and the Procedure applies to all businesses that manufacture or market diesel emission control technologies regardless of their location.

9.7 Potential Impact to California State or Local Agencies

The proposed procedure will not create costs or savings, as defined in Government Code section 11346.5 (a)(6), to any State agency or in federal funding to the State, costs or mandate to any local agency or school district whether or not reimbursable by the State pursuant to Part 7 (commencing with section 17500, Division 4, Title 2 of the Government Code), or other non-discretionary savings to local agencies.

9.8 Estimated Costs

As noted previously, the Diesel Emission Control Strategy program is voluntary. Those manufacturers that wish to market diesel emission control strategy devices in California consistent with the Diesel Risk Reduction Plan may decide to comply with these Procedures in order to gain verification. The diesel emission control strategy verification procedure requires both emission and durability testing. Fulfilling this testing requirement should constitute the direct costs to the manufacturer when complying with the diesel emission control strategy verification procedure. In order to facilitate the verification process and aid manufacturers who participate in the diesel emission control strategy program, multiple forms of equivalent data and testing can be submitted for review. Where the testing is conducted, if it is done in-house versus contracted out, and what testing is actually done will significantly affect the total price of complying with ARB testing procedures. Additionally, depending on the technology being submitted for review, additional testing might be required before verification is approved. Because of these factors, costs associated with the diesel emission control strategy verification procedure can vary wildly between manufacturers. In order to estimate a representative cost to manufacturers, ARB staff is making the assumption that all manufacturers will contract out for all testing and that they will strictly follow the diesel emission control strategy verification procedure and will not be able to provide equivalent data from other

projects. Costs of special testing or setup requirements are not addressed as they are too variable and would be determined on a case by case basis. Estimates are based on multiple sources and should encompass a range of possible prices.

Generally speaking, cost estimates for running an engine dynamometer test, not including cost of fuel, starts at about $85.00 per hour. The set-up cost for a standard engine or vehicle is estimated at $15,000 per vehicle or engine, depending on the type of engines or vehicles. The cost for one cold and one hot test is estimated at $4,000 while any additional hot test is estimated to be $1,500 (See Table 13).

Staff has estimated the costs to applicants for participation in the verification program, as shown in Table 13, below. It must be noted that the cost estimates assume all testing would be unique to the verification program, even though the proposal allows the use of existing data where appropriate.

Table 13. Representative Verification Testing Costs

Cost Item	Engine Testing	Chassis Testing
Set-up Costs per engine or vehicle	$15,000	$15,000
Cost per one cold and one hot-start	$4,000	$4,000
Cost per additional hot-start	$1,500	$1,500
Emission Testing per engine or vehicle	$29,000	$11,500
Durability Testing	$51,000	$64,500
In-Use Compliance Testing	$232,000 - $580,000	$304,000 - $760,000
Total Testing Costs	$312,000 - $660,000	$406,500 - $862,500

The above estimates include in-use compliance testing costs which could vary widely. The amount of in-use compliance testing required depends on the performance of the tested units. A minimum of 8 units to a maximum of 20 units would be tested for in-use compliance. Actual testing costs might be lower as the proposed Procedure and U.S. EPA programs utilize a common statistical basis allowing data collected for one program to potentially fulfill the requirements of the other. Thus, a business with preexisting data generated from U.S. EPA in-use compliance testing may be able to apply this towards ARB in-use compliance requirements. Additionally, in-use compliance testing only applies to businesses, which sell more than 50 units of a specific model of a verified diesel emission control system in California. Because of the above, the cost for in-use compliance can vary significantly. For those businesses selling less than 50 units, or which have existing, appropriate data, there would be no cost for in-use compliance.

The total costs for all requirements, including emission reduction, durability, and in-use compliance can range from zero for a manufacturer that has previously generated data fulfilling all the proposed requirements, to $862,500 for a manufacturer which would have to generate all its data specifically for the proposed Procedure. The projected values agree with actual costs provided by a manufacturer. A manufacturer of diesel emission control strategies provided estimates on how much it would cost to comply with the proposed regulation. The manufacturer's estimated cost was between $400,000 and $850,000 dollars to complete all the requirements of this regulation. These figures support staff's estimates.

10 ENVIRONMENTAL IMPACTS

No direct environmental impacts can be associated with the staff proposal, as the proposal would simply institute a methodology and protocol for evaluating diesel emission control strategies. Emissions benefits due to use of the strategies evaluated through this Procedure will be estimated as part of the development of regulations or other programs to implement the strategies.

11 COST-EFFECTIVENESS

Because no direct emissions benefits are associated with the staff proposal, no traditional cost effectiveness can be calculated. When staff proposes rules to implement in-use controls for the various categories of diesel engines, it will provide more detailed estimates, taking into account the specific issues associated with each category.

12 CONCLUSION

The proposed verification procedure, as described herein, would provide a way to thoroughly evaluate the emissions reduction capabilities and durability of a variety of diesel emission control strategies. The proposal provides sound guidelines for evaluation, while retaining the flexibility needed to reduce the burden on applicants and allow speedy implementation of the Diesel Risk Reduction Plan. The ARB staff recommends that the Board adopt new sections of 2700 to 2710, Title 13, California Code of Regulations, set forth in the proposed Regulation Order in Appendix A.

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